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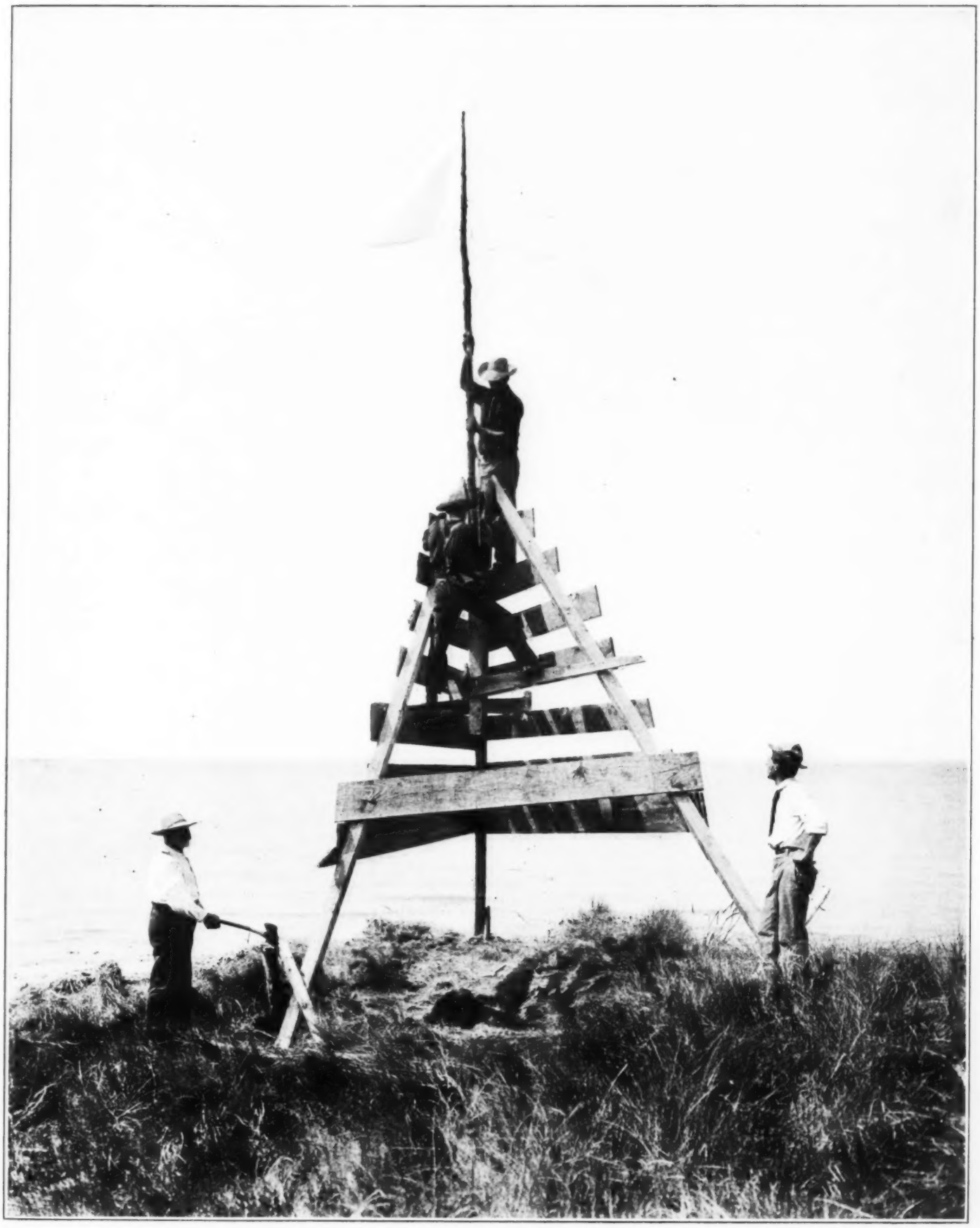


Government surveyors erecting a signal to mark a triangulation point.

HOW CHARTS ARE MADE.—[See page 424.]

On Stresses in Transparent Materials*

As Revealed by Polarized Light

By E. G. Coker, F.R.S., M.Inst.C.E, Professor of Engineering, University College, London

THE study of the stresses in materials may be said to have originated with the celebrated discussion by Galileo Galilei, as to the way in which a beam, built into a wall at one end, resists a load which it carries at its outer extremity. In his dialogues, published at Leiden in 1638, Galilei shows a figure of such a beam, and propounds a theory based on the assumption that the material is absolutely rigid. He arrives at the conclusion that, in such a case, there are uniform tensions across the section of the beam, and that these tensions act about the bottom edge as a fulcrum. The question raised by Galilei concerning the state of stress in a beam does not appear to have been subjected to any kind of experimental test at the time, but the problem served as the starting point of a long discussion of the action of a beam, and gradually an approximately true explanation of the distribution of stress was reached as a result of the work of many different observers.

The results of all these experimental and theoretical inquiries into the internal conditions of materials when subjected to load, formed the foundation of a new science of the strength and elasticity of materials, which at the present day has succeeded in covering a tremendous field of inquiry, although it has by no means exhausted the possibilities of the subject, especially in its relation to the constructional problems of engineers and architects.

In considering the means which are available for the purposes of research and investigation on the strength and properties of materials, it is somewhat remarkable that most of our present experimental knowledge has been obtained by purely mechanical measurements, in which uniformity of stress is necessary over a length, an area, or a volume of a body, and in which the majority of the measurements have been at the surface, the assumption usually being made that the condition of the interior is practically identical. The required conditions of uniformity of stress very much restrict the scope of experimental inquiry, for in the great majority of cases requiring examination, variation of stress in a short distance is enormous, and the stress at one point of a body differs so much from another in its neighborhood that an average value is useless.

Fortunately, other means are available for examining the nature and kind of distribution of the stress in a body. Among the first to make investigations upon the optical behavior of transparent materials under stress was Sir David Brewster, who, as early as 1814, found that if a piece of glass is slightly heated it shows effects similar to those which are seen in some natural crystals when examined under polarized light. He also showed that if a piece of glass is subjected to an external force it exhibits brilliant color effects so long as the load is applied, but immediately this is removed the colors disappear. The application of these phenomena to practical problems was at once apparent to Brewster, and he suggested that it would be possible to obtain valuable information concerning the stresses in the arched rings of bridges and like structures by such means.

In order to show the effects produced in polarized light by the action of stress in a transparent material, we may conveniently take a simple example, such as a strip of transparent material under tension, and arrange the optical apparatus, so that when the strip is unloaded no light is transmitted, the effect of a moderate tension causes the specimen to appear a grayish white, and, as the stress increases, the color changes by insensible gradations to a lemon yellow, then to a reddish purple, and with a very little increase of stress to a well-defined blue. With a further increase of stress the scale of colors is approximately repeated for twice the intensity of stress, and the relation of color to stress is found to be approximately that given in the comparative table below. We have, therefore, a recognizable and easily understood color-scale to mark the intensity of tensional stress in a material.

For simple tension and compression, the relative retardation of the rays which produces the color effect is proportional to the stress, and to the thickness of the material. In such cases, therefore, the stress intensity may easily be determined by observing the color bands, bearing in mind that both tension and compression produce similar effects, if changes in the thickness of the material are allowed for. Thus, if we take the case of a transparent beam subjected to a uniform bending moment, a system of color bands is obtained, and by inspection of the color fringes the distribution across the section can be determined approximately.

TABLE I.

COMPARATIVE TABLE OF TENSION AND COMPRESSION STRESSES CORRESPONDING TO A GIVEN COLOR.

Order.	Color.	Stress.
I.	Black	0
	Gray	3.5
	White	5.5
	Straw	8
	Orange	10
	Brick Red	10.5
	Purple	11
II.	Blue	13
	Yellow	18
	Red	21
	Purple	22

It is seen that the stress varies uniformly from a maximum tension at the under side to nothing near the center, and it then changes sign and increases uniformly to a maximum compression stress at the upper side of the beam, in exactly the same manner as occurs in a metal beam subjected to the same kind of loading.

This case indeed affords one of several instances where the results of optical experiments can be compared, not only with mechanical measurements of strain but also with the theory of the distribution of stress in materials, and the experimental determinations for a transparent material show a very good agreement with strain measurements and with the precise theory. We can, therefore, feel very confident in more complicated cases that the stresses in a transparent model are similar to those in a metal. For example, a beam with a notch cut in it may be taken, as shown, and the effect of the notch is seen to increase the stress in the material very considerably. The distribution is now much more complicated than it is in a simple beam; the neutral axis has moved toward the notch, while the color effects show that the maximum stress is at least twice as great as that in a beam without a notch.

To apply this kind of experimental work to cases of practical importance, it is desirable that the material used shall possess similar physical characteristics to those possessed by steel, iron and other materials in general use by engineers.

The physical properties of glass very closely resemble those of cast iron and natural stones, but measurable double refraction can only be obtained when thick plates are stressed to nearly the breaking point of the material. Glass is, moreover, an extremely difficult material to shape, and specimens can only be produced by laborious processes. Other transparent materials, like xylonite, have physical characteristics resembling mild steel and wrought iron, for example, their load-extension diagrams up to fracture are very similar. Xylonite is a preparation of nitro-cellulose, which is not so transparent as glass, and is usually slightly tinted; but it has the very important advantage that specimens may be fashioned quite readily with ordinary wood and metal-working tools, and with reasonable care the contours of the specimen show no signs of residual stress after shaping.

Experimental investigations of the stress distribution in engineering structures and machines, by aid of transparent models, involves the construction of complicated shapes, which are most convenient to make and examine if they are of large size, but Nicol's prisms, for large scale models, are not available. Polarization of the light is therefore preferably effected by reflection from black glass when a circularly polarized beam is required, and by refraction through clear glass for plane polarized light.

In one of the arrangements designed for such work a parallel beam from an arc lamp is directed on to a black glass reflector at a suitable angle, and is rendered parallel to its original direction by reflection from a second silvered mirror. It then passes through a quarter wave plate, so that the object is illuminated by a circularly polarized beam. The usual inverse arrangement of quarter wave plate and small Nicol's prism, or its equivalent, is used for the analyzer. In order to dispose all the apparatus in a line the reflecting box may be doubled, but this offers little practical advantage, except in cases where plane polarized light is used, and it is required to rotate the plane of polarization to obtain the directions of principal stress.

For this latter purpose it is more convenient to polarize by refraction through thin glass plates arranged in a frame capable of rotation about the axial direction of the beam, and although the polarization is, in general, less perfect than by reflection, yet it is sufficient for the purpose.

With the arrangements thus described a parallel beam of polarized light may be obtained, which is limited only by the size of the lens system of the arc lamp projector. It is also possible to obtain a very large field of view by employing a diverging beam which is ultimately reduced to a thin pencil of rays in order to pass through the analyzer. To effect this a large plano-convex lens may be used, which need not be of a high degree of optical perfection, except in the important particular that the material of which it is composed must be quite free from internal stress.

With such an arrangement a magnified image of the model can be projected on a screen for examination, but if the object is very large the lenses required become so costly that other means have to be adopted, and a reflecting polariscope may then be employed with advantage.

We must now inquire by what means it is possible to measure the stresses produced in a transparent material by any given system of loading, and it will be apparent that if the stress is merely simple tension or compression its intensity can be read off at once by reference to the color scale already established. Many cases of this kind occur in practice. If, for example, a simple ring is cut through one side and loaded after the fashion of a hook it is very severely stressed at its principal horizontal section, and the distribution across this section must consist of tension or compression stress only.

We may therefore read off the stress at any point of the section, and obtain curves of distribution such as those now shown, in which the stress intensities for several loads have been determined and plotted.

In this case the experiments agree fairly well with calculations of the stress distribution in a hook of this cross section, and they also show the interesting result that, as the load increases, the neutral line moves away from the tension side. In most cases, however, the stress distribution is more complicated to deal with.

Any case of stress in the plane of a plate can always be represented by two principal stresses at right angles, and if the magnitude and direction of these are determined for all points the stress distribution is solved.

In order to obtain an experimental solution of this problem, it is necessary to inquire into the relation of the optical effect to the principal stress intensities at a point, and it is easy to show this by simple experiments. If, for example, we take two equal tension members and subject them to the same uniform stress intensity the color effects will be precisely the same for each, while if they are superposed to interpose a double thickness the color effect is the same as that produced in a single member under twice the stress.

Experiments on three or more superposed members readily verify for simple tension and compression that the optical effect is simply proportional to the stress intensity, and also to the thickness of the plate. If, however, two equally stressed tension members of the same thickness are crossed, the common area gives a dark field, showing that the stress effect of one neutralizes that of the other. The same dark field is produced if an equally stressed compression member is placed with the direction of stress parallel to that of the tension member, and we may readily verify in all cases that tension and compression stresses in the same direction add their effects, while stresses in directions at right angles subtract them.

The latter result is of chief importance since the stress at any point of a plate can always be represented by two stresses p and q at right angle s, and their optical effect is therefore proportional $p - q$. The value of the stress difference may therefore be determined by matching the optical effect produced at the given point with that produced on a simple tension or compression member, or, better still, by reducing

*Transactions of the Optical Society.

the optical effect to zero by a single tension or compression member set along one of the directions of principal stress, and stressed until a dark field is produced.

The laws which the optical effects obey may be at once utilized for a variety of cases of practical interest. An example is furnished by piping for transmitting fluids under pressure. The action of water, or other fluid, in a pipe can be imitated by applying a uniformly distributed pressure to the interior of a ring, where the application of a uniformly applied pressure produces a stress distribution in the circular ring of a perfectly symmetrical character.

The arrangements of the color bands show that there is a very large stress at the interior surface, diminishing rapidly at first and afterward more gradually as the outer surface of the pipe is approached. In this case there is known to be a radical compression stress accompanied by a circumferential tension stress, and the optical effects produced at any point are proportional to the algebraic difference of their intensities.

In a thick cylinder of these proportions the radial stress is not large, and its intensity can be determined independently, but the combined effects of both stresses have been measured here, and are compared with the values found from calculation in the diagram now shown.

A fair agreement with the theory is apparent, and it is really closer than the curves indicate, owing to the full pressure recorded on the gage not being effective.

In this problem a measurable fluid pressure is applied to the cylindrical surface of a ring in such a way that no essential part is obscured from view.

Fluid pressure of water or other liquid is applied by the action of a small hand pump, the piston of which is actuated by a screw to force oil at any desired gage pressure into the annular space between two metal disks, which latter are bolted together to hold a retaining ring shaped like a Bramah cup-leather to prevent leakage of the fluid. This latter ring projects slightly beyond the periphery of the disks and carries the transparent ring to be stressed. The cup-leather is itself so thin that a pressure of a few pounds per square inch will burst it, but when the ring is mounted upon it even a pressure of 2,000 pounds per square inch may be applied with safety. A very small percentage of the total pressure is absorbed by the cup-leather, and is not exerted upon the ring, and when due allowance is made for this the agreement between experiment and theory is very close.

In cases where calculation is impossible, as often happens in many forms of engineering construction, the magnitude and direction of each principal stress at a point must be determined separately.

A measure of the principal stresses at a point can be obtained, if advantage be taken of the fact that the stress causes a change in the thickness of material proportional to the sum $(p + q)$ of the principal stresses. If, for example, both stresses are tensions, there will be a lateral contraction of $(p + q)/mE$, where E is the modulus of direct elasticity, and m is Poisson's ratio. Both these latter quantities can be determined, and the sum of the streses can be measured if an extensometer is used of sufficient accuracy to measure the lateral contraction. The values of the physical quantities E and m differ very much for different materials, but for the artificial transparent material used here they are much smaller than for a metal, and the difficulty of this kind of measurement is therefore much lessened.

A fair value of E for xylonite is 300,000 in pound and inch units, while m has a value of about 2.5, so that for each 1,000 pounds of stress intensity, the corresponding lateral contraction for plates of the usual thickness of ⅛ inch is 1/6000 of an inch. To measure such a quantity to an accuracy of within 1 or 2 per cent, it is advisable to use an instrument capable of indicating a change of at least one hundredth of this quantity; such changes have been measured with fair accuracy by using a lateral extensometer capable of detecting a change of about half a millionth of an inch.

In this arrangement a frame carries a calibrating screw, the point of which bears against the plate of transparent material, and is immediately opposite to a second piece, the inner end of which is lightly pressed against the plate by a spring, while the outer end presses against the short arm of a lever controlling the angular position of a mirror. Any change which takes place in the thickness of the specimen between the measuring points causes a rotation of a mirror, and this change can be measured by observing the movement of a spot of light which is reflected in the usual manner. The observations can be checked by the calibrating screw, which is provided with a graduated head for this purpose. It will be noticed that the measuring points simply bear against the face of the bar, and do not penetrate it, so that the length over which a measurement is made can be accurately determined.

The whole of the measuring apparatus is moreover supported on a pair of light steel springs attached to an independent clip, so that indentations are avoided at the points of measurement, while errors caused by the weight of the instrument on the measuring points are eliminated.

The extensometer readings give a measure of the sum of the principal stress at a point in the plate, and their difference is found by an optical measurement. Each stress is therefore determined by measurements which are comparatively easy to carry out, although considerable care is required to obtain accurate values, especially if one quantity is much smaller than the other, since minute errors of observation become a large percentage of the value of the lesser quantity.

Reference has already been made to the fact that any state of stress at a point in a plane may be represented by a pair of stresses at right angles through the point, and whatever may be the character of the stress distribution in a plane, the directions of principal stress can always be represented by two systems of orthogonal curves spaced in a manner which the external loads and boundaries of the plate dictate. If, for example, two symmetrically disposed notches are cut in a tension member, it is clear that equally-spaced tension lines above and below must be crowded together as they pass the narrow neck, and those at the sides will probably come closer together than do those in the center, thereby indicating a high stress intensity at the middle points of the notches.

Lines of principal stress may be drawn from the data provided by experiment, if advantage is taken of the property possessed by stressed material of causing the two systems of retarded rays to vibrate, one in the direction of the major principal stress, and the other in the direction of the minor principal stress.

Between crossed Nicol's prisms a loaded plate shows, in general, dark bands, which mark the positions of all points where the directions of principal stress correspond to the principal planes of the polarizer and analyzer, and by varying the angular positions of these latter a series of bands are obtained, each corresponding to definite directions of the axes of stress.

If, for example, the case of a simple tension member is taken with notches in the form of fine cuts in it on each side, dark bands are observed, and these change their positions as the axes of the optical apparatus are rotated. A diagram can be constructed from such observations to show the directions of stress at any place. If lines of stress at some distance away from the slits are now considered, they will clearly be parallel and perpendicular to the sides of the plate, but as the former set approach the discontinuity, they must bend toward the center line in order to pass through the narrow neck, since they cannot maintain their continuity in any other way. The observations of the lines of equal inclination show how they are guided, and it is evident that they come close together at the extremities of the slits, and that there is an intense stress at these points.

Other lines of principal stress at right angles to the first set are also indicated by the measurements, and the two systems give a kind of framework diagram, which latter shows the direction of the principal stresses, and therefore completes the solution of the problem. The stress distribution in a plate cut to a required form, and stressed in an arbitrary manner by forces in its own plane, may therefore be determined experimentally.

The complete experimental solution of the stress distribution in a body may be illustrated by an investigation of the action of a rivet near the edge of a rivetted joint, since we can determine the sum $(p + q)$ of the principal stresses, their difference $(p - q)$, and their directions. In this problem we can no longer neglect either principal stress, and it is in general necessary to determine both their directions and magnitudes. If the uniform tension stress in the full section of a plate is represented by equally spaced lines in the direction of stress, we may expect to find alterations in their directions and spacing as they draw near to the discontinuity produced by the rivet, and an optical examination shows that the lines of stress approach one another very closely as they pass around the rivet, and afterward diverge again if the overlap of the plate is sufficient to permit this.

It is not difficult to explore the whole of a plate stressed in this way, by determining both the sum and difference of the stresses at a sufficient number of points on the lines of stress so found, and some of the measurements, for the cross section passing through the center of a rivet in a plate in which both the overlap and the widths of metal on each side of the rivet are equal to the diameter of the rivet, show that the tensile stress at the horizontal cross section reaches a high value, while below the rivet an even greater compression stress is produced. The measurements of radial stress along the sections chosen give marked compression close to the rivet, and it is worthy of note that they are very nearly zero at the outer boundaries of the plate, results which confirm the general accuracy of the measurements. Other measurements of a similar kind show that the action of a rivet produces an intense stress at the hole, sometimes reaching five times the stress in the full plate. In a transparent model this is often accompanied by permanent overstress and local yielding, which tend to equalize the stress in the material.

We have seen that the complete determination of the distribution of stress in a plate subjected to forces in its own plane involves the determination of the directions of the lines of stress, and the measurement of both the sum and the difference of the principal stresses at each point, since these latter cannot in general be measured separately.

It is therefore apparent that this kind of investigation offers great advantages for the measurement of shear stress, since the optical effect is proportional to the difference of the principal stresses, and therefore varies according to the shear stress at a point. The quantitative determination of shear stress is accordingly of a simple kind, since the delicate measurements of the change of thickness in a plate are not necessary.

The variation of stress in a rectangular plate when subjected to nearly pure shear has been examined with some care, and it has been shown that, when the length is greater than 1.75 times the breadth, the shear stress rises to a maximum value near the end of the plate, and has a slightly smaller value at the center. When, however, the length of the plate is less than 1.75 times the breadth, the shear stress reaches a maximum at the center, and has a parabolic distribution.

The application of optical methods of investigation to problems which arise in the testing of materials shows that something may possibly be gained by an examination of familiar methods of testing.

Among the cases which have been examined is that of the usual shear test of materials.

Shear tests are usually made upon bars of rectangular or circular cross section gripped in such a manner that shear stress is applied to two similar and equal sections at a finite distance apart, and load is applied until the material is sheared across these sections. In this way a mean value of the shear stress at rupture is obtained, which is of some value, but it affords no indication of the behavior of the material up to the elastic limit. It seems probable that the assumption of uniform shear stress across the section is not justifiable, and within the elastic limit it is clearly not so, as is immediately obvious from the color effects now shown, where the stress distribution is due to a shearing force applied to a rectangular section.

Commencing from the top-most edge the color effects indicate that the stress is a maximum here, and diminishes rapidly as we proceed along the section, until it becomes sensibly uniform, and then as the lower edge is approached the stress again rises rapidly and reaches its greatest intensity at the lower edge. This increase of stress beyond that at the upper edge is due to the bending of the specimen in the grips, and it indicates that failure will occur here.

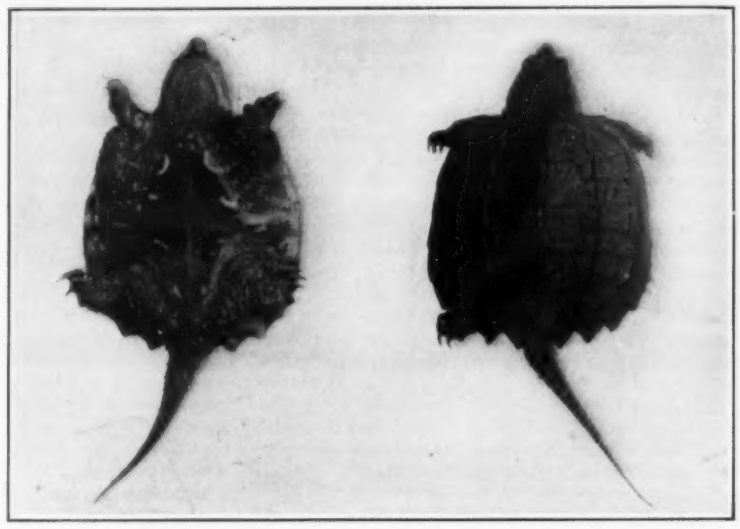
Specimens of circular cross section show a different distribution, and it is evident that tests of dissimilar cross sections of the same material are unlikely to give uniform results in shear unless these differences are taken into consideration.

It would not be difficult to supply other examples of the use of optical determinations of stress in models, but the cases already dealt with are probably sufficient to show that results of practical importance can be obtained in this way, which might be difficult, if not impossible, to arrive at by any other methods of investigation used by engineers.

The Influence of Elements in Steel

In a paper by Mr. W. A. Janssen, recently read before the American Foundrymen's Association and reproduced by *The Iron Trade Review*, Cleveland, Ohio, the author states that notwithstanding all that has been said concerning the harmful effects of phosphorus and sulphur in steel, the occluded oxides and gases, such as iron oxide, Fe_2O_3, and an indefinable oxide, probably FeO, free oxygen, nitrogen and occluded slags are the real causes of many of the troubles of the steel maker.

Fig. 3.—Young of snapping turtle (Chelydra serpentina); life size.



Figs. 4 and 5.—Upper and lower views of the young of the snapping turtle.

Turtles, Terrapins, and Tortoises of the United States

An Important Branch of the Reptilia

By Dr. R. W. Shufeldt

We have in our United States fauna quite a variety of turtles and tortoises, and it would seem that they have received but scant attention at the hands of those writers that pass what science has learned about them into channels where such knowledge comes before the general reader. Indeed, in popular publications, these most interesting animals have, to a large extent, been overlooked or passed by, for the reason that most nature students have given their time and attention to the study of other groups of vertebrates. Even science has been guilty of similar negligence; and where one work on turtles has been published, about a dozen or more have appeared on birds, on botany, and even on fishes. Still, there is a large literature, both popular and scientific, on the Reptilia as a class, which, by the way, is, by several good authorities, divided into ten orders, more than half of which number are extinct. Four of them, however, have been created to contain existing groups of animals, namely the peculiar lizard of the East Indies, the *Hatteria*; the Crocodiles, the Snakes, and the *Chelonia*—our tortoises and turtles being chelonians or reptiles having a shell of some sort (carapace and plastron), in which all parts of the body are harbored save the head, limbs, and tail. This arrangement, which is quite a modern one, excludes in its grouping such creatures as the frogs, toads, and their allies, which form the Class *Batrachia*, the species and genera composing it being batrachians.

There are several kinds of chelonians, and we designate them as turtles, terrapins, and tortoises—the latter name being derived from the French word *tortis*, meaning twisted, and it doubtless came into use from the curiously formed fore legs of the common land tortoise of Europe. All three of the various species of chelonians are represented in our North American fauna—that is, the tortoises, the turtles, and the terrapins. The marine species are all true *turtles*, like the Leather-backs, the Logger-heads, the Green Turtles, and the Hawk's-bill Turtles. None of these will be taken into consideration here, though I have enjoyed excellent opportunities to study all of them in nature, particularly in the South Atlantic, the Bahamas, and the Gulf of Mexico; they are large, salt water forms, more or less known to every intelligent reader.

Most people are familiar with our Snapping Turtles, and these will be considered in the next article following the present one. Then we have the Mud Turtles, of which there are two genera, including nine species. Of the true Terrapins (*Chrysemys*) there are no fewer than fifteen well-marked and different species, with probably a few subspecies, and some of these are among the most interesting and beautiful turtles that we have in this country. The young are very often even more beautiful than the adults, their colors and markings being very striking and brilliant. This is equally true of another genera of our terrapins (*Malacoclemmys*) containing six species, the celebrated Diamond-back Terrapin being of their number. To another genus of terrapins (*Chelopus*) have been relegated four other species, one of these being our well-known Spotted Terrapin or Turtle, so common in the swamps and ponds throughout the Eastern States. Many authors include our Wood Terrapins here (*C. insculptus*); but in several respects they seem to be very different chelonians from our Spotted Pond Turtle just referred to. Then

Fig. 1.—Common musk turtle (Aromochelys odoratus); male three quarters natural size.

there are some half a dozen species of "Box Turtles," terrestrial tortoises of the genus *Terrapene*, and three true land turtles or gophers of the genus *Testudo*.

This enumeration will give a fair idea of the number of species of chelonians we have in the fauna of the

Fig. 2.—The young of two species of terrapins; natural size.

United States. Most of them I have seen alive upon many occasions; quite a number of them I have kept alive for the purpose of study, while I have studied all of them in museum collections. Within the last week or ten days I have had a dozen of the different species referred to above living in various aquaria and other receptacles in my study at home. Some of these I have captured myself in the ponds and streams as they occur about Washington, and for others I am indebted to Mr. Edward S. Schmid, of this city, who often has as many as 150 or more turtles of different species at his well-known Emporium for Pets.

The anatomy, physiology, and psychology of turtles is of extreme interest to science; and for animals so low in the scale they are far more intelligent than most people think. A while ago I kept as a pet, for several years, a specimen of an old male Wood Terrapin. He must have been about eighty years old, when circumstances compelled me to part with him, and I presented his turtleship to the Zoölogical Society of London, where he was, at last accounts, contented and happy. That old chelonian knew every inch of the floor space in the apartment where I lived in New York City; moreover, he knew every member of the family. When I was writing at my study table, he would often come and rest on my slippered foot, ever and anon glancing up at me in the most friendly manner. At meals he had the habit of coming across the floor to my chair, and, standing on three legs, he would raise himself up a little, begging for something to eat by moving one of his fore-limbs up and down—shaking his free fore-flipper or leg at me, as it were. He was especially fond of strawberries, which is the case in a good many other terrestrial species.

I have photographed three turtles from life to illustrate the present article; one of these is shown in Fig. 1, it being a fine, male, subadult specimen of the common Musk Turtle, which has received the scientific name of *Aromochelys odoratus* owing to the not very pleasant odor it gives off when captured. This species occurs from Canada to the Gulf east of the Mississippi, and it sometimes makes its appearance in great numbers in the spring in certain localities. The principal color of the adult of this species is an earthy brown, a distinctive mark being the two yellow stripes on the sides of the head—one passing through the eye; these easily distinguish it from another species resembling it superficially known as the Mud Turtle. Our Musk Turtles are strictly aquatic species, and capable of remaining under water for a longer time than any other tortoise known to me; they are savage little fellows, snapping at you the minute you handle them. To be sure, they come ashore to deposit their pure white, ellipsoidal eggs. Sluggish streams are their favorite resorts, and they move about actively on the bottom seeking their food. This consists of small fish, when it is possible to capture them, or of various worms and similar live forms. They are voracious fellows, and move about with a certain quick, stealthy movement, quite unlike other river or pond turtles. Sometimes they seize a worm or fly on the fisherman's hook, and are thus made captive. Their extreme agility eminently fits them for the life they lead; and they are remarkably cute little things when first out of the egg, the

markings on the under side of the upper shell or carapace being very striking and pretty. From birth to adult specimens, I have made photographs of all the life-stages of this truly quaint and pugnacious representative of our eastern chelonians.

In passing I may say that the so-called shell of a turtle is divided into an upper part or *carapace*, and

Fig. 6.—An old spotted turtle; two thirds natural size.

a lower part or *plastron*. In the species just described, the carapace is much arched and rather elongate; and, indeed, structurally this reptile, as in the case of all of our chelonians, presents much in its organization of great interest to the morphologist. But these are matters which it would be out of place to discuss in the present article.

Among the most beautiful specimens of turtles that we have are the young of such species as the Yellow-bellied Terrapin; Lesuer's Terrapin; the Diamond-back; the Geographic Terrapin Turtle or Map Turtle, and others. Here we have pure grays and elegant greens, with yellows, scarlet, and other rich tints, rarely spread over the entire surface, but generally exhibited in curious figure patterns, in stripes, in concentric spots, or other designs of decided beauty and attractiveness.

The little chap standing on tip-toe, with the entire top of the carapace squarely in view, and the fore part of his head just sticking out of the water, is the young of the Yellow-bellied Terrapin (Fig. 2), the companion in the picture being the young of Lesueur's Terrapin—a very beautiful little form. The mid-longitudinal line of its carapace is *serrated* on side view. The Cumberland Terrapin (*C. elegans*), both young and adult, have a bright scarlet patch on either side of the head.

While I have at my hand the life histories of a large number of our chelonians, with photographs I have made of the various species, it is obviously out of the question to even attempt to touch upon the appearances and habits of them all in such a brief contribution as the present one. It is better to be more thorough with a single species than to skim over the biographies of the many forms now known to us. Some day I may take up others, but for the present we may review some of the better known facts in the life history of the common Snapping Turtle.

The appearance of the adult of this species is pretty well known, while this is not altogether the case with the young. This being so, I have illustrated the latter in Figs. 3-5 here, these being reproductions of photographs I made of two individuals. They are given natural size, and each is probably about a year or more old. When fully adult, the animal may weigh as much as forty pounds, and possess a carapace between fourteen and fifteen inches in length. As will be observed in Figs. 3-5, the more or less flattened carapace of this species is conspicuously serrated behind, the serrations forming some four graduated notches upon either side—the shallowest ones being outermost. On the under side, the plastron is narrow and small, leaving much of the body besides the limbs unprotected by shell. The tail is very long and tapering, and its under surface becomes, in the adult, encased in semi-osseous plates of considerable size. Young specimens, as shown in Fig. 4, possess some ornamental color markings on the plastron, a part of the shell which becomes a dull chrome in the mature animal. Above, the carapace may be of a rich brown, which is frequently shaded with olive. The limbs and head, too, are of a dark brown superiorly, while beneath they are of a yellowish flesh color, sometimes tinged with an extremely pale olive or greenish yellow. In some large specimens, the mid-length of the carapace may measure between 27 and 30 inches and its width over 10 inches.

Snapping Turtles range in nature from southern Canada southward through the United States and Mexico, to Ecuador in South America. From the time of birth till its death, this species of turtle is a vicious and combative reptile, and bites of the old individuals may be so severe as to be quite a serious matter in some cases. It is one of the most abundant and best known of all of our chelonians, being found in a great many sluggish, muddy streams and rivers, as well as in some ponds and marshes.

When I was a boy and lived at Stamford, Connecticut, I very well remember that some old farmers, when they captured a good-sized "snapper," would place the reptile in the swill-barrel to fatten. In such a receptacle of plenty, it seemed to increase in size more rapidly than in its native environment; it certainly became so fat and bloated in body that it could not move about when taken out and placed upon the ground. In this condition it was considered a great delicacy for "turtle soup" and occasionally stews. At this season (June) they are in great demand in the city restaurants, and fetch from 10 to 12 cents per pound in Washington markets.

Snapping turtles of this species (*Chelydra serpentina*) possess unusual powers of extending the head and neck, either directly forward or over the back—sometimes laterally. So quickly is this accomplished, and so suddenly is that part of the body withdrawn again, that it defies human eyesight to either follow or appreciate the action. It is done with the intention to bite and injure an enemy, or anything living that may be threatening or annoying it. In such an attack, with its keen, sharp-edged jaws, even a half-grown snapper may easily bite off a child's finger or toe; older specimens can with ease perform similar surgical feats upon grown persons.

Over and again it has been proved that snapping turtles in nature feed only when entirely under water. This seems to be a necessary condition for them; and it has further been observed that when it captures some of its living prey—for snappers are *entirely* carnivorous—on the banks of the stream or pond where it lives, it will at once drag it beneath the surface of the water, and devour the victim of its agility on the bottom. Fish and water-fowl of various kinds constitute its principal fare—especially the former. Some naturalists aver that the snapping turtle can only swallow its food when its head is entirely under water. Personally, I have made no experiments to prove that such is the case. I have, however, upon several occasions come across a big fellow of this species, not far from the bank of a muddy stream, in about two feet of water. Doubtless I have overlooked many a one in similar places; for the keenest eyes will fail to detect the presence of the reptile if the stream is muddy enough to hide the bottom. Motionless he lies, looking for all the world like a great, rough, flat stone, upon the surface of which has grown a luxuriant crop of waving green moss, while the semi-protruded head and largely concealed limbs are really the only parts responsible for arousing suspicions as to the object being an old *Chelydra serpentina*, patiently awaiting the passage over him of a fish, in that he may shoot out his neck and head quicker than a flash of lightning, and seize it to partly appease his ever-voracious appetite.

Along in June, in the northern part of the range of

Fig. 7.—Front view of mud turtle; about four fifths natural size.

the species, female snapping turtles resort to the shore, to lay some two dozen or more round, white eggs, with thin, hard, and tough shells. Should one meet, in early summer, in New England for example, a large snapping turtle, prowling about in the neighborhood of a pond, marsh, or slow stream, one may be very sure that it is a female, hunting for a suitable place in which to deposit her eggs. She will soon select a soft, damp place; with her fore feet make an excavation into which she can crawl, and cover herself over so as to be practically out of sight. When completely hidden to her liking by jarring the loose earth down about her, she will lay her full clutch of eggs. When this feat has been accomplished, she brings herself as nearly as possible into an erect posture, which causes the loose earth on her carapace to roll off and cover the eggs so they will not be likely to be observed by passers-by.

Big, vicious, and voracious as our Snapping Turtle is, it is dwarfed and more than eclipsed by its giant cousin, the Alligator Snapping Turtle of the principal streams emptying into the Gulf of Mexico, from western Florida, to include the State of Texas. This species is the *Macrochelys lacertina* of science, and it anatomically as well as morphologically closely resembles the Snapping Turtle. It is also a light brown in color, which pales out to some degree beneath. Old specimens will weigh upward of 145 pounds, and possess a carapace over two feet in length down its middle line. There is an enormous mounted specimen of light brown in color, which pales out to some degree beneath. Old specimens will weigh upward of 145 pounds, and possess a carapace over two feet in length down its middle line. There is an enormous mounted specimen of this Alligator Snapper at the New York Aquarium, where Dr. Townsend once invited my attention to it. They are abundant in the Mississippi, having all the habits of the last-described species, only far more pronounced; for it can with ease bite a broom-handle in two; snap off a man's hand, with other chlydrine feats on a grand scale: Its strength is something marvelous, and it will bite a piece out of a two or three pound fish with a single snap of its ponderous jaws, as clean as though it had been removed by a stamp-die. Thus it swallows in big gulps; and in a week, in confinement, it will devour at least two or three fish aggregating some six or seven pounds in weight. This turtle possesses a peculiar organ in the cavity of its great mouth, which, when put in motion, which it can do at pleasure, resembles some sort of a grub or larva swimming about in a small circle. A hungry fish stands no chance when it passes such a lure as this, for its great, brown, moss-backed owner, resting as motionless as a mountain in the ever rolled water at the bottom of the stream, with the gaping jaw resembling another cleft, nearby rock, constitutes, on the whole, a cunning trap, with deception written all over it, which no fish is likely to escape.

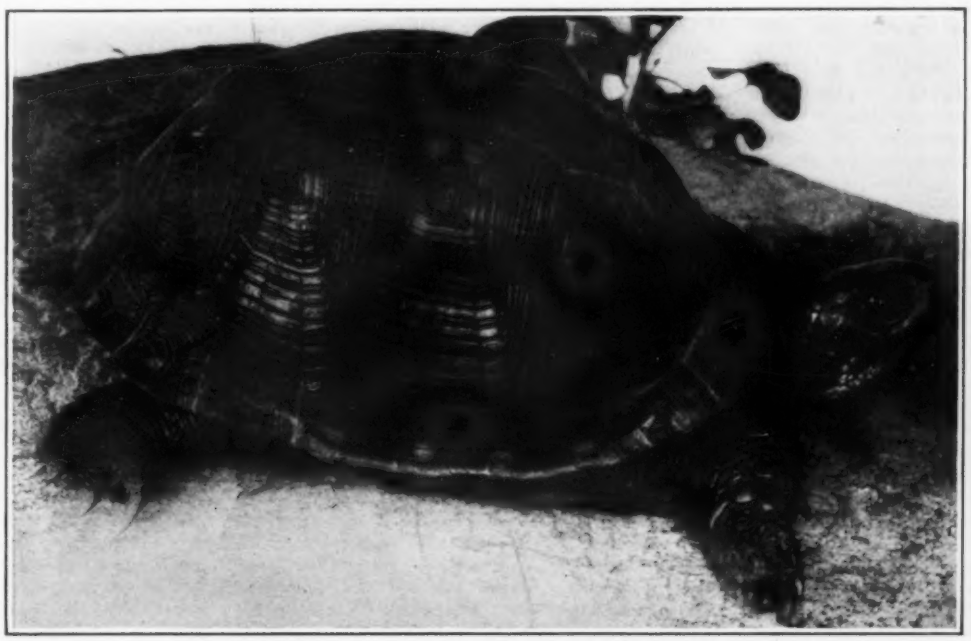


Fig. 8.—Common box tortoise (Terepene carolina); life size.

The Synthesis of Caoutchouc*

A Survey of Various Attempts to Produce Artificial Rubber

By B. D. W. Luff, F.I.C.

THE synthesis of caoutchouc was recorded long before any very definite ideas were formulated as to its construction. Pure caoutchouc is a hydrocarbon having the empirical formula C_5H_8; its molecular weight, however, cannot be ascertained by means at present available, owing to the fact that it is a colloid. Moreover, the number of simple derivatives which may be obtained is extremely limited and these, being chiefly amorphous and almost impossible to obtain in a pure condition, afford very little insight into the nature of the parent substance. The most readily prepared is the bromide, $C_5H_8Br_2$, a white amorphous solid formed by treating caoutchouc with bromine in chloroform solution; it is, however, almost impossible to obtain a specimen which approximates sufficiently closely to the empirical formula, to be considered as pure. Perhaps the most interesting derivative is the diozonide, which can be prepared by passing ozone into a chloroform solution of caoutchouc; on evaporation a vitreous solid is obtained, melting at 50 deg. Cent. Harries (*Ber.*, 1905, 38, p. 1195) found that this had a molecular weight corresponding to the formula $C_{10}H_{16}O_6$. On hydrolysis this yields equimolecular proportions of levulinic aldehyde and levulinic aldehyde peroxide, the latter subsequently breaking up into levulinic acid and hydrogen peroxide. Hydrochloric acid and oxides of nitrogen also combine with caoutchouc, forming compounds which are more or less ill-defined and need not be discussed here.

More interesting results, however, are obtained on submitting caoutchouc to destructive distillation. As far back as 1833 a patent was granted to Barnard for the invention of "a solvent not hitherto used in the arts" which was obtained by distilling rubber from an iron retort; this oil could be used to dissolve caoutchouc itself, resins, fatty bodies, etc., and, moreover, could be used as an illuminant. The work was subsequently taken up on more scientific lines by various investigators, including Dalton, Liebig, Himly, A. Bouchardat, and Gregory, their results being embodied in various publications issued between 1835 and 1840, but in all cases their efforts were more or less disjointed.

The most systematic attempt to isolate and examine the various products present in the crude distillate was made by Greville Williams in 1860. He obtained (1) a liquid boiling at 37 deg. Cent. to which he gave the name "Isoprene"—the molecular formula of this body was found to be C_5H_8; (2) a large proportion of a hydrocarbon boiling at 170 to 173 deg. Cent., which was identical with a body previously obtained by Himly, and called caoutchine—the molecular formula of this was $C_{10}H_{16}$, and it may be noted that it has since been proved to be dipentene; (3) a fraction boiling above 300 degrees to which he gave the name "Heveene."

Some years later, in 1879, Gustave Bouchardat, son of A. Bouchardat, undertook a detailed investigation of isoprene, in the course of which he examined the action of hydrochloric acid; he noted that an addition product was formed but under certain conditions the action of the acid resulted in the formation of a solid mass, not containing chlorine, but having in fact the same percentage composition as the isoprene itself. In describing this body he says, "it possesses the elasticity and other properties of rubber itself. It is insoluble in alcohol, swells up in ether and also in carbon bisulphide, in which it dissolves after the fashion of natural rubber." Moreover, he noted that on distillation it yielded the same hydrocarbons as in the case of the natural product.

This, then, was an important step in the synthesis of caoutchouc; in fact, in order to make this complete, all that was necessary was to prepare isoprene, a comparatively simple hydrocarbon, from elementary materials; at that time the only source of isoprene was rubber itself.

Although Bouchardat regarded the product he had obtained as identical with natural rubber, yet the fact that it was elastic and behaved in a similar manner toward solvents did not suffice to establish definitely the relationship existing between them.

Bouchardat's results received confirmation in 1882 at the hands of Tilden (*Chem. News*, 1882, 46, 120) who observed the polymerization of isoprene when treated with nitrosyl chloride, a reagent which he had used in connection with work on terpenes. In discussing isoprene he remarked that one of the chief characteristics of this body was its conversion into true caoutchouc or India rubber when brought into contact with certain chemical reagents; he pointed out that this was of great practical interest as, if isoprene could be obtained from some other and more accessible source, the synthetical production of rubber could be accomplished. Two years later Tilden succeeded in obtaining isoprene by passing the vapors of turpentine through a hot tube, the yield, however, being very small in proportion to the amount taken; nevertheless the solution of the problem, at any rate from a commercial point of view, appeared to be in sight, as the initial material was fairly abundant and the cost not excessive.

The outcome of the work of these two investigators was that the caoutchouc molecule was shown to be formed by the union of a number of molecules of isoprene, i. e., it was a polymer of this body, and moreover this union or polymerization could be brought about by treating the isoprene with suitable reagents.

To them must be given the major share of the credit for laying the foundation of the numerous processes since suggested for preparing synthetic rubber. The importance of their observations will be apparent when we consider that this method of polymerizing a simple hydrocarbon is at present the only one by which the complex rubber molecule may be said to have been reproduced. Their work affords a very good illustration of the value of making careful note of changes occurring during a reaction; what organic chemist has not at some time or another succeeded in obtaining, instead of the crystalline solid he had hoped for, an uninviting plastic mass which was promptly discarded as of no consequence? However, Bouchardat and Tilden had in their favor the knowledge that the isoprene which they used had been obtained from rubber itself, so that the identity of their product with this body would the more readily suggest itself.

Subsequently Wallach (*Annalen*, 1887, 238, 88) observed that isoprene underwent polymerization on exposure to light with production of a rubber-like mass. Tilden (*Chem News*, 1892, 65, 265) also drew attention to this phenomenon and at the same time recorded the fact that the material obtained in this manner could be vulcanized with sulphur in the usual way, this pointing to a close relationship existing between the synthetic and the natural material.

Some idea of the quantitative nature of the polymerization may be gathered from the statement by Weber (this Journal, 1894, 13, 11) to the effect that from 300 grammes of isoprene, after a period of nine months, 211 grammes of caoutchouc was obtained.

The synthesis of isoprene and as a corollary that of caoutchouc was accomplished by Euler in 1897 (*Ber.*, 1897, 30, 1899) and his work together with that of Ipatiew (*J. prakt. Chem.*, 1897, 55, 4) established the constitution of this body, showing it to be β-methyldivinyl, $CH_2{:}C(CH_3).CH{:}CH_2$. This supported the view entertained by Tilden some time previously.

The auto-polymerization of isoprene was confirmed later by Pickles (*Trans. Chem. Soc.*, 1910, 97, 1085); in this case the change was not complete after upward of three years. The product possessed a certain amount of elasticity but was not equal to Para rubber, resembling rather that obtained from immature trees; the comparison, it may be noted, was based on unvulcanized samples. Pickles, furthermore, prepared derivatives with the aid of bromine and oxides of nitrogen, in each case obtaining bodies apparently identical with those resulting from the employment of natural rubber.

The nature of the polymerization of the simple isoprene molecule to the caoutchouc complex was also discussed by this worker, whose views are as nearly as possible in accordance with observed facts. The union of the C_5H_8 groups is held to be a chemical one, caoutchouc being represented by a chain of an indefinite number of these units connected at the ends to form a ring. This conception, which is perhaps the simplest of the many put forward, has been contested by Harries and others, but in the meantime may be accepted as it does not involve the assumption of molecular aggregation of an unnecessarily vague character.

With the synthesis of isoprene in 1897, the problem of the synthetic production of caoutchouc, at least from an academic point of view, could be regarded as solved. For some time, however, no serious attempt was made to put it on a satisfactory commercial basis.

One of the first methods which attracted attention was that suggested by Heinemann in 1907, which consisted in passing a mixture of acetylene, ethylene, and methyl chloride through a hot tube when isoprene should result.

$$C_2H_4 + C_2H_2 + CH_3Cl = CH_2{:}C(CH_3).CH{:}CH_2 + HCl.$$

This reaction, however plausible it might seem, did not appear to take place as desired, with the result that the method was abandoned; it is interesting, however, as being the first instance in which an industrial concern had endeavored to make the synthesis a commercial success.

Another type of process which at this time received treatment at the hands of a number of workers was that in which, following the lines indicated by Tilden, turpentine was submitted to "cracking" processes. This line of work, which at first sight seemed fairly promising, was ultimately abandoned as supplies of the initial material were becoming somewhat limited and the tendency was for prices to rise; in any case, the yield of isoprene was never satisfactory.

In 1909, owing no doubt to the rapid rise in the price of rubber, the problem was attacked in a systematic manner in this country by a group of chemists which included among others Perkin, Fernbach, Weizmann, and Matthews; in Germany, too, the Bayer and the Badische companies had taken the matter up and from this time onward an enormous number of processes have been outlined which, at any rate, may be said to be alive with possibilities.

To give anything like a detailed account of these would be outside the scope of this paper, but it will suffice to give types illustrative of the varied ways by which the desired end may be attained. It must be clearly understood, however, that the instances which are quoted are merely by way of illustration and in no way to be considered as likely to lead to better results than could be obtained in the case of most other methods.

In 1884 Tilden suggested that not only isoprene but its homologues should be capable of polymerization in a similar manner. This was indeed found to be the case, as subsequent investigators showed that many unsaturated hydrocarbons containing conjugated double bonds exhibited this property, the products thus formed varying from resinous masses to rubber-like bodies. Chief among them may be mentioned butadiene (or erythrene), $CH_2{:}CH.CH{:}CH_2$, and dimethyl-butadiene, $CH_2{:}C(CH_3).C(CH_3){:}CH_2$. It is not surprising then to find these compounds forming the basis of methods for obtaining synthetic caoutchoucs.

In considering the materials available as the starting points for suggested syntheses, it would be as well to confine our attention to those of which the supply is fairly abundant. Among these coal tar at once suggests itself, and indeed a process has been worked out starting from *p*-cresol. This is first reduced by the Sabatier method, the product oxidized to β-methyladipic acid, and by elimination of the carboxyl groups, together with two atoms of hydrogen, isoprene is obtained. In a similar manner, starting with phenol, butadiene can be prepared; the number of stages necessary to complete the reaction, however, renders the process of little value.

The low-boiling fractions obtained in petroleum distillation have also been suggested as the starting point for obtaining isoprene. The normal and iso-pentanes which are present are converted into dihalogen derivatives and from these two molecules of HCl eliminated. The chief difficulty in processes of this type is in arriving at the desired diahalogenide and many methods have been suggested with a view to surmounting this obstacle.

From starch isoprene may be prepared in a variety of ways; most noteworthy is the method described by Perkin (this Journal, 112, 621) which consists in bringing about fermentation in such a manner that amyl alcohols are produced in much greater proportion than is usually the case; these are converted into dichloroderivatives and two molecules of HCl split off by means of soda-lime, isoprene being thus produced. Butadiene can be prepared in a similar manner from butyl alcohol.

From starch again ethyl alcohol may be obtained, and according to Ostromyslenski (this Journal, 1916, 69) if this is passed along with a little air over heated copper gauze a proportion of the alcohol is oxidized to acetaldehyde; the mixture of aldehyde and alcohol is

*Journal of Chemical Industry.

then passed over heated alumina whereupon water is eliminated and butadiene produced.

$$CH_3CHO + CH_3CH_2OH \rightarrow CH_2:CH.CH:CH_2 + 2H_2O.$$

This process is certainly suggestive and appeals to one by its very simplicity, but the success will naturally depend on the yield of butadiene; as a general rule pyrogenetic reactions of this type do not take place in one direction only. It is worthy of note that Ostromyslenski (*loc. cit.*) has quite recently published a series of papers dealing with new methods for preparing these hydrocarbons; these are remarkable if for nothing else than the exhaustive consideration which he has given to the subject, as an instance of which may be cited one paper in which he describes no less than twenty-nine new methods for preparing butadiene.

Cellulose has also been suggested as raw material for preparing isoprene; a method has recently been worked out for obtaining lævulinic acid in considerable quantity by submitting sawdust to the hydrolytic action of dilute acids under pressure. With the aid of phosphorus trisulphide the acid so obtained is converted into methylthiophene and by passing this over heated copper along with a stream of hydrogen, isoprene is formed, H_2S being eliminated.

These instances then may be taken as typical of the many processes put forward as being likely to lead to the commercial preparation of isoprene and other closely related bodies.

The production of the necessary unsaturated hydrocarbon is, however, merely the first stage in the synthesis of caoutchouc, the next step being to bring about polymerization by some means.

At the outset it was generally recognized that agents hitherto employed in experiments on a laboratory scale did not give at all satisfactory yields of rubber and the need for a more efficient method was evident. One of the most promising was that proposed by Harries in 1910 (this Journal, 1910, 502) which consisted in heating isoprene in a sealed tube with glacial acetic acid; subsequently the same worker announced that better results could be obtained by the use of sodium, the polymerization to caoutchouc taking place almost quantitatively in the cold. Curiously enough this same agent had already been patented in this country by Matthews and Strange, the former having made the discovery in 1910; the patent however had not been disclosed, so that evidently it was an instance of different investigators arriving at the same result independently of each other. Harries prepared and described two series of rubbers resulting from the polymerization of butadiene, isoprene, etc., on the one hand with sodium as the condensing agent, and on the other hand using acetic acid. The products obtained by the use of sodium, although resembling rubber in so far as their physical properties were concerned, did not behave similarly when submitted to chemical treatment. The acetic acid products presented a closer analogy from a chemical standpoint, but were inferior physically.

It is interesting to note in passing that Greville Williams in 1860 distilled his isoprene over sodium, but most probably the two bodies would not be left in contact for any considerable time, at any rate not long enough for any appreciable polymerization to take place.

Without venturing to give any definite opinion as to the future developments in connection with the many processes hitherto evolved for producing synthetic rubber, the present position may be put briefly as follows:

There is no doubt that caoutchouc-like bodies have been prepared by means similar to those outlined above; as to whether these can be regarded as true caoutchouc is a matter of doubt. It will be understood that on account of the colloidal nature of this body the question cannot be settled by determining such physical characteristics as would serve to identify a crystalline solid such as camphor. In the case of a body such as the latter the specific properties which render it of interest can be directly attributed to a well defined molecular structure, the reproduction of which by whatever means insures possession of these properties. In the case of caoutchouc, however, this cannot be brought about with certainty. Indeed, many of the proposed methods do not purport to give a product chemically identical with the natural material. In the case of the polymerization of butadiene (C_4H_6), it is manifestly impossible to obtain a body having an empirical formula C_5H_8, although physically the resulting mass is perhaps the most satisfactory of any obtained up to the present.

Harries (this Journal, 1912, p. 733) holds the view that caoutchouc obtained from isoprene with the aid of acetic acid is identical with that occurring in nature, basing this assertion on a study of the ozonides. That derived from the synthetic material is said to give on hydrolysis lævulinic acid and lævulinic aldehyde only, the reaction proceeding with the same velocity as in the case of the natural derivative. On the other hand Steimmig (this Journal, 1914, p. 268) dissents from this opinion, the results of his experiments on the hydrolysis leading him to the conclusion that there is present, in addition, a body produced by the asymmetric polymerization of isoprene. Harries, however, maintains his original attitude and attributes Steimmig's results to the use of impure isoprene.

The synthetic caoutchouc obtained by polymerizing isoprene in the presence of sodium, however, is not identical with the natural product as neither lævulinic acid nor lævulinic aldehyde is formed on submitting the ozonide to hydrolysis.

It might be urged that the chemical characteristics are of relatively little importance if the material fulfils all the needs of the manufacturer, and this is undoubtedly the correct view to take. Up to the present, however, the quantities of synthetic rubber produced have been so small as not to admit of a comparison being made with the natural material on anything like a satisfactory scale. The rubber manufacturer knows too well that a substance which might truthfully be called a "tough elastic mass" or "caoutchouc-like body" need not necessarily be as good in every way as the product of the plantations in the East.

A glance through one or two specifications to which various rubber articles must conform would quickly convince the reader that a product destined to replace caoutchouc for all purposes must possess properties of a very varied character.

Even if a synthetic body were obtained which could be said to compare favorably with the natural article, the price would obviously become a determining factor in the chance of success; it is here that an industrial process would encounter almost insuperable difficulties. At the time when chemists began to turn their attention toward synthetic rubber the price of this commodity was abnormally high, reaching as much as 12 shillings and 6 pence per pound in 1910. Since then, however, there has been a steady fall, reaching as low as 2 shillings and 4 pence per pound in 1915. This is accounted for by the plantations coming into bearing, the products thereof occupying a very prominent place in the world's markets. The recent growth of the plantation industry, and the very different conditions which a synthetic product has now to face compared with those obtaining in quite recent years, can be seen at a glance from the following tables:

Plantations—area under rubber.

	Ceylon. Acres.	Malaya. Acres.
1901	2,500	.....
1912	230,000	621,621

Tons of plantation rubber exported.

	Ceylon. Tons.	Malaya. Tons.
1904	35	.....
1912	6,697	18,956

World's supply of plantation rubber.

	Tons.
1912	28,500
1915	98,000

The rapid strides which have been made in the cultivation of rubber will thus be evident, and as there is every prospect of the yields increasing for some time to come this is bound to react on the price, and it is generally assumed that unless a synthetic product can be put on the market at about 1 shilling 3 pence per pound there is little hope of the natural material being superseded.

As chemists, perhaps, it would be gratifying to know that another triumph has been won in the industrial field, but whatever the outcome may be, it is well to remember that the chief factor militating against success is the result of scientific energy expended in other directions, that is to say, in raising the product of the plantation to the highest pitch of perfection.

Preservation of Natural Color in Plants

So long ago as 1908 Prof. J. W. H. Trail described in the *Kew Bulletin* a method which he had worked out for fixing the green color in plants. By placing the plant for a shorter or longer period in a boiling solution of copper acetate dissolved in acetic acid, a combination of the copper salt with the chlorophyll was formed which rendered the color permanent when the specimen was exposed to the light after drying or placed in a preservative solution such as alcohol.

The method deserves to be more widely known than it seems to be among those interested in preparing plant specimens for exhibition in museums or for lecture purposes. It is essentially a method the results from which gain by experience; different plants lend themselves to the treatment with different degrees of success, and require very different periods of treatment; the time for which it is necessary to keep the plant in the boiling solution varies from one minute to forty minutes, according to the action of the copper salt upon the plant. If the action is proceeding satisfactorily, a period of one to five minutes should suffice; the end of the operation is easily judged by the color or by treating two different specimens for different periods; a specimen that by such comparison appears to require longer treatment can always be reimmersed to get the desired effect. Many plants, notably the leaves of evergreen shrubs, are more difficult and generally less satisfactory in the ultimate color, probably owing to the presence of mucilaginous or decomposition products or tannins. These require long treatment, varying from twenty to forty minutes; after the first immersion they turn yellowish, and then after a time the yellow gradually gives place to green, generally an olive-green. Other plants, notably Aucuba, fail entirely, as they pass from the yellow to a muddy-brown or black color.

After treatment the plants should be washed (like photographic prints) in running water for about two hours. They are then dried under as light pressure as is compatible with keeping the plants from twisting, or, after shaking off as much water as possible, may be dried in hot sand. In many cases the plants are rendered so flaccid by boiling that sand-drying is difficult or impossible. Plants that have required long boiling not infrequently revert to a bad color when sand-dried.

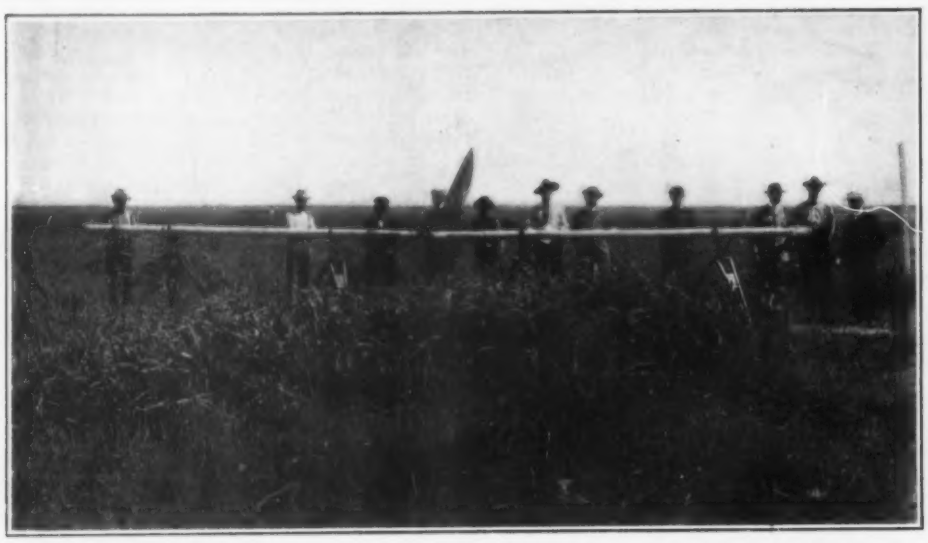
Young parts of plants green better than old; better results may be expected from "spring" leaves than from "autumn" leaves.

A stock solution is made by saturating commercial strong acetic acid with powdered copper acetate. For treatment, dilute the stock solution with water in the proportion of three or four parts of water to one of stock solution. The solution is heated in a non-metallic vessel, glass beakers being probably the most suitable, and wooden, not metal, forceps should be used for manipulating the specimens.

This method has been used at the Natural History Museum for some time past in the preparation of plants for exhibition purposes, and good results have been obtained with cryptogams as well as flowering plants; ferns especially give satisfactory results, and, as Prof. Trail has noted, fresh green Algæ can be successfully treated. Proceeding out of these investigations, experiments have been made with the object of preserving the natural color of seaweeds or of introducing a color that is natural and permanent. The exhibition of Algæ in the Botanical Gallery, shows an appreciable success for the red Algæ and some satisfactory results for the brown Algæ. It is proposed to present an account of these experiments shortly before one of the scientific societies.—*A. B. Rendle in Nature.*

America and Load-Line Regulation of Ships

It is a curious fact that the United States has not yet framed any regulations to govern the loading of merchant vessels. Yet even new and small maritime nations have specific rules on this important matter, and it is not surprising therefore that the Americans are now considering what can be done in this direction. One of the first and most important factors in the safety of a ship at sea is the position of the load-line, and when they decide to put into force the rules of the International Convention on the Safety of Ships at Sea, to which they sent a number of delegates, they will have gone a good way toward limiting the draught to which vessels can load. It is true that under these rules a vessel may load down very deeply provided she is sufficiently closely subdivided, but for practical spacing of bulkheads it is found that the ratio of the freeboard to the load draught must not be too small, so that deep loading could never take place. The British authorities, of course, go further than the International Convention in fixing the maximum draught to which a vessel can load; and after the bulkheads have been spaced to give the requisite safety at a given draught this draught must not be greater than that which would be granted under the load-line tables. The question of an international load-line is to receive consideration after the war, but in the meantime the British committee appointed to report on the matter has issued its findings, though they are not to be put into force in this country until some more suitable time. The work of the committee was very carefully and scientifically done; and if the United States is really seriously searching for load-line regulations those laid down by the committee would at least form a basis for a temporary measure, and the matter could be put on a firm footing when the International Conference on Load-line has been held.—*Engineering Supplement of the London Times.*



Measuring a base line in starting a survey. These duplex bars were used before the introduction of the invar tape measures.

Reading microscopically in precise measurement in the field.

How Charts Are Made*

Important Work That Requires Great Skill and Care

THERE are few people who realize and therefore fully appreciate, the enormous amount of both technical and practical detail necessary in the making of a chart for the use of the navigator and nautical man.

During the past year the United States Coast and Geodetic Survey distributed nearly 163,000 of these charts, which represented nearly half a million impressions on the printing presses. While this single feature that produces the finished product means much careful work, the preliminaries in connection with the making of a chart, covering many months of hard, thoughtful, accurate work, are not in even a small measure understood by the average person.

The charts are used for the safe guidance of vessels, not only by the Navy, Coast Guard, and Merchant Marine, but by privately owned vessels as well.

To appreciate the great value of a nautical chart one has to imagine himself a surveyor in a land which is strange to him, standing on the shore of some body of water which has never appeared on any map.

Look upon this water as a highway leading to a fertile area abounding not only in mineral resources but rich for the farmer, and which must be made accessible to the pioneer through the efforts of the surveyor. This highway must be cleared of all dangers and made safe and passable for traffic. To the surveyor, the method is clear, but he must be able to mark the safe road for those who will use it. There are channels to be followed; dangerous reefs and shoals that must be located and avoided, so he draws and completes a plan or outline of the best and safest way for ships to go and sends forth this information to the navigator.

The body of water that the surveyor is viewing is to him not different from other navigable streams. There are apparently several channels, dangerous reefs, and shoals that must be located, and then their exact positions placed on a nautical chart before this water may be safely navigated. It is necessary for the shore line, mountains, and other topographical features to be properly located and also made part of the chart so the officer guiding his ship may, by these means, determine the exact position of his vessel with reference to the unseen dangers below the surface of the water.

In this or any new undeveloped country there are no monuments which are the results of careful surveys. The surveyor therefore must determine the position of his starting point by observations upon objects in the heavens.

Conditions such as these are found in portions of Alaska and our other possessions, and existed in the country used for illustration before accurate charts were made. To insure absolute safety and to protect human life and commerce all unsurveyed waters must be charted, and the charts must be kept corrected as to changes made by the hand of man and by nature. Insurance companies will not insure vessels plying through uncharted waters except on the payment of exorbitant rates. Naturally, the passenger and the consumer of the freight must pay this extra cost. Therefore a general and clear description of the work of making or constructing the chart which contributes largely to the safety of the waters wherever they may be is of vital interest to everybody.

STARTING THE WORK.

The engineer in starting his work makes a rough sketch or diagram of the area to be surveyed. This sketch often bears little resemblance to the final survey, but serves as a preliminary index to the progress of the work.

In beginning surveying operations it is generally desirable to select a level stretch of land on which a line, called a base line, can be measured with a standardized metal tape. A point, which will serve as one end of the base line, is selected and we will call this point the starting point.

The latitude and longitude of the starting point must be exactly determined. This process requires very accurate astronomical observations, and may briefly be defined as *finding distances from the equator* (latitude) and *from a reference meridian* (longitude) by means of these observations.

DETERMINATION OF THE TRUE NORTH.

To anyone seeking only general knowledge of this important subject the above explanation will suffice for the first step. The operation to determine true north is the next step of interest. After the latitude and longitude of the starting point are determined the direction of true north is determined from this point, usually by observations on the north star (Polaris).

A signal pole is then placed on the ground exactly in the true meridian of the starting point and this enables the surveyor to determine at any time the angle of deviation of the magnetic needle from true north. It might be well to state for general information that the magnetic needle does not point true north (except at a very few places), as the deviation varies at different places and for different times.

To enable navigators, surveyors, engineers, and others properly to allow for this deviation, observations are made at many points. The true north point is known as zero, and the number of degrees east or west of this zero to which the magnetic needle points, is the variation of the compass, which is shown on each nautical chart.

In the first operation the position of a *starting point* upon the earth was determined by observations upon objects in the heavens—latitude and longitude. In the second operation a direction from this point true north was ascertained also by astronomical observations. From this direction the variation of the magnetic needle may be obtained. In the third operation a line was measured from this starting point, and the direction of this line was determined by reference to the true north, ascertained in the second step.

BASE-LINE MEASUREMENT.

The line measured is known as the base line. Its length must be very accurately determined, for it is used as the basis in the computations of the lengths of hundreds of other lines that are not actually measured. Formerly the measurement of a base line was made by bars, sometimes placed in ice to maintain an even temperature. Now, a tape of a nickel-steel alloy is generally used, which shows so little change in length caused by differences of temperature that its results are as accurate as those of the old and cumbersome bar. When the length and direction of the base line are determined, its ends are two points whose exact positions upon the earth are known, one having its position observed and the other computed. The base line is the shortest distance between these points, and its length is accurately known.

TRIANGULATION.

A third point is selected off to the side of the base line, and the lines connecting this new point with the base ends will form two sides of a triangle of which the base line is the third side. Then the first triangle of the triangulation system has been located. Its angles must be accurately measured and satisfy the geometric condition that "the sum of the angles of a triangle must equal two right angles" (180 degrees). Now, having ascertained the angles of this triangle and knowing the length of the base line, which is one side of the triangle, the other sides may be computed by the trigonometric proposition that "when any three elements (sides and angles) of a triangle are known, at least one being a side, the other elements may be determined by computations." When the other sides of the first triangle are computed, those sides are used in place of base lines for new triangles and the triangulation sysetm is, in this manner, continued over the area to be surveyed. If the sides of the triangles are very long, the curvature of the earth must be considered in their computation.

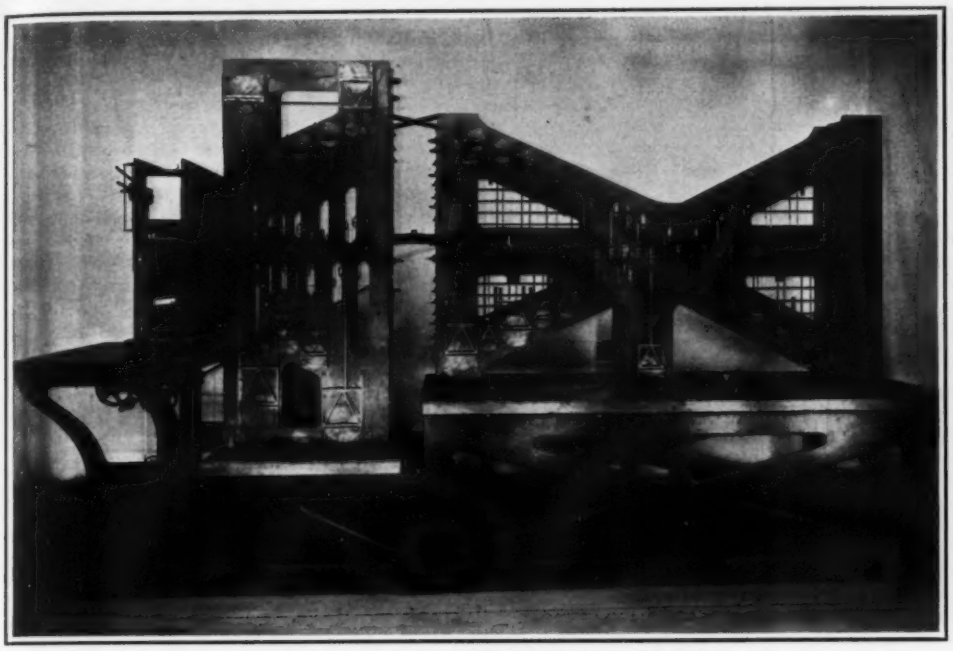
Starting from a point whose exact latitude and longitude, and also the true meridian passing through it, are determined by observations on the stars; then from this point measuring a line whose direction and length are ascertained; then with this line as a side of the first triangle, forming a series of triangles whose angles and length of sides are precisely determined, the latitude and longitude of the vertices of all the triangles are computed from these data with an accuracy substantially equal to that of the starting point. By this means a controlling triangulation net has been placed over the area of which a topographic survey is to be made.

MAPPING THE LAND AREAS WITH THE PLANE TABLE.

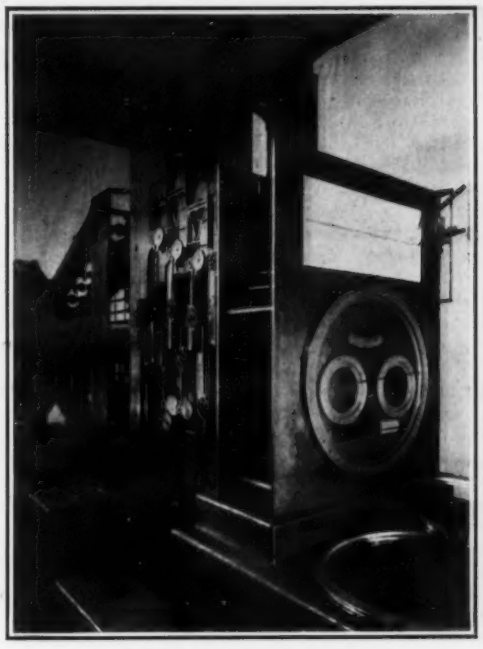
Before the measurement of the angles of the triangles, signals were placed over the triangulation stations. The topographic party, when ready to begin work, is equipped with a plane table, alidade, stadia rods, and a sheet known as a "projection," on which the lines of latitude and longitude are drawn to a selected scale; and the vertices of the triangles, called triangulation points or stations, are plotted in their correct geographic positions. By the plane-table method, field notes are not necessary, both the survey and drawing being made in the field at the same time.

The plane table, with the projection clamped to its

*"Elements of Chart Making," by E. Lester Jones, Superintendent of the U. S. Coast and Geodetic Survey, issued by the Department of Commerce.

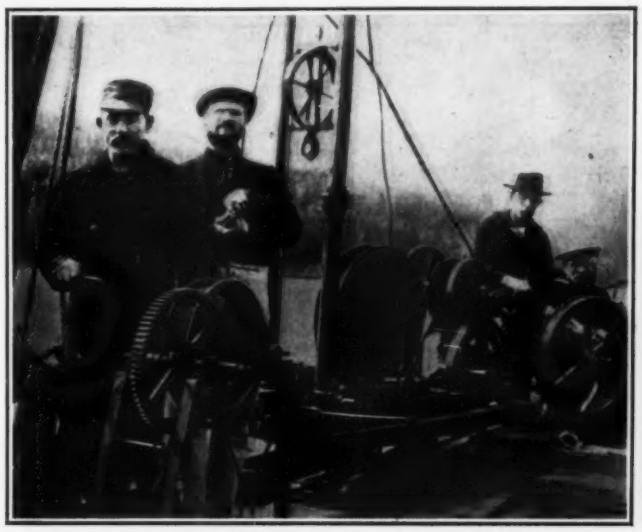


Right-hand side of the tide calculating machine.



Tide dials and curve plot.

Plain table work under difficulties.

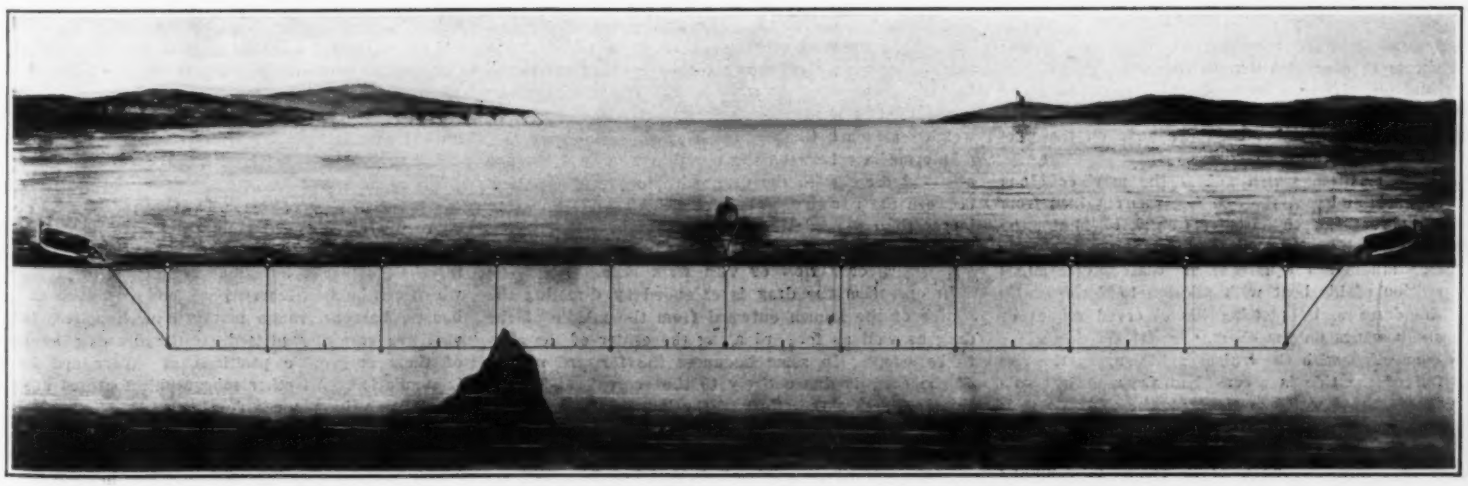


Making a deep sounding.

Climbing a cliff to make an observation.

On their way to establish a triangulation station on Mt. St. Elias.

Summer survey work in Alaska.



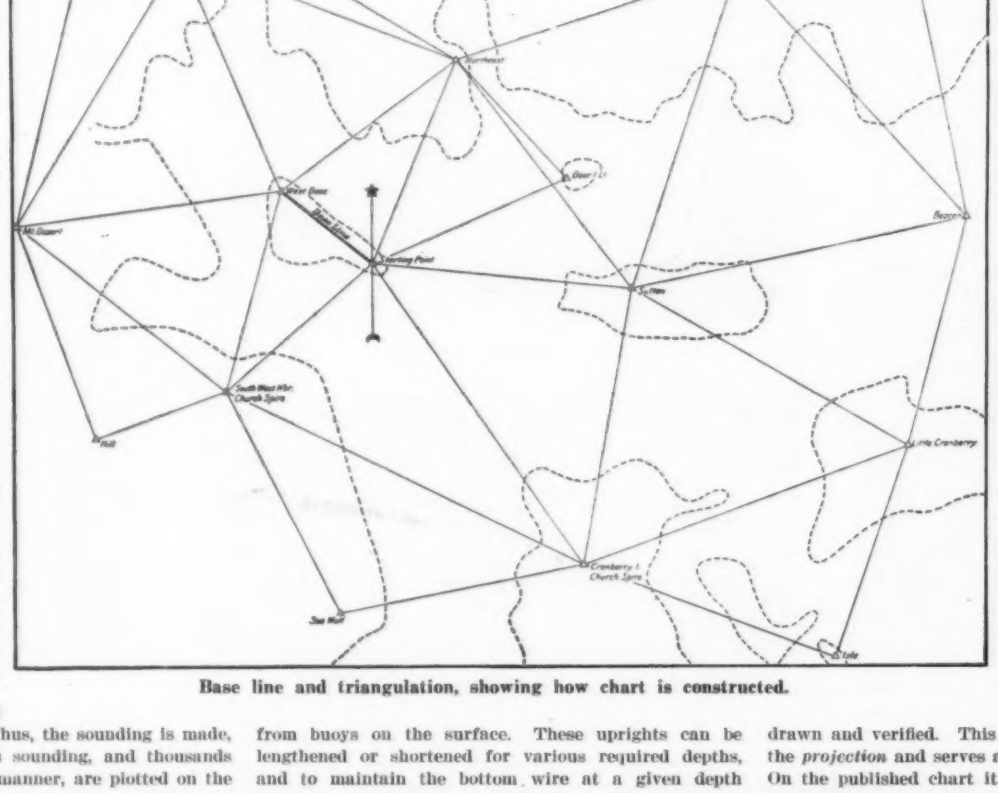
How the wire drag is operated for investigating under-water conditions when making marine surveys.

top, is so set up at points in the field that the triangulation stations on the sheet are in exact relation with respect to direction to the signals over the same stations on the ground.

The alidade consists of a telescope attached to a straightedge so that the two are in parallel vertical planes. If the straightedge is in contact with a point representing the place occupied by the plane table and the telescope is sighted at an object and a line is drawn along the straightedge on the topographic sheet, then the object is somewhere on this line. This gives the *direction* to the object. Its *distance* is ascertained by a reading made on the stadia rod held on the object. In making the survey the observer places the alidade on the point on the sheet which corresponds to the point on the ground over which the plane table has been set; the stadia man follows the shore line, stopping at every bend. The observer locates the position of the stadia rod at each bend of the shore line, connects these positions on the sheet, and the shore line is thus surveyed and mapped.

Other features than the shore line, such as prominent buildings, roads, woods, etc., are located in the same manner; that is, by placing the stadia rod on the object, then with the alidade ascertaining its direction and distance, and plotting this on the sheet.

In beginning the survey, the position of a point was established; a line was measured from this point; this line was taken as the base of the first triangle; the lengths of the other sides of this triangle were computed and used for bases for new triangles; these triangles were extended over the area to be surveyed; the points of these triangles were used to establish the position and orientation of the plane table; the topography was filled in by the plane table and a map was made. With one or more operation this map becomes a chart—a guide for the mariner by which he locates the safe channels and avoids the hidden dangers of the waters.



Base line and triangulation, showing how chart is constructed.

SURVEYING THE WATER AREAS.

The agency which performs the operation which changes the map into the chart is known as the hydrographic party. This party usually does its work from a launch; sometimes from a large vessel; sometimes from a rowboat. The party consists of two observers with sextants, a recorder, a leadsman, and a crew. The position of the sounding is determined by the observers in the moving boat by sighting with sextants upon the signals over the triangulation points or other established conspicuous objects; the leadsman drops his line overboard and ascertains the depth of water; he calls out the depth and the observers announce the angles; the recorder enters the angles and the depth in his field book. Thus, the sounding is made, located, and recorded. This sounding, and thousands of others made in the same manner, are plotted on the field sheets in exact relation to the triangulation stations and other objects on land and also to the shore line. All aids or dangers to navigation are similarly plotted on field sheets and later appear on the published chart, with the soundings.

This information, which guides the mariner along safe channels and past the dangers, was obtained from boats by observations upon objects on shore. Later the mariner, by making observations upon the same objects or other landmarks equally well located, determines the position of his boat with relation to the channels and the dangers, by plotting his observed angles or compass bearings on the chart.

In connection with the hydrographic survey the rise and fall of the tide is observed at frequent intervals and the depth of water is given on the chart as it is at the average low tide.

Surveying our waters for navigational charts has in the past largely been done by means of sounding with the lead line, and for the reason of the limitations of that method the information as to the form of the bottom so obtained is restricted to points more or less separated. In other words, the hand lead, weighing about 12 pounds, is attached to a line and cast overboard at various intervals to ascertain the depth of water, and does not give a complete or final knowledge of certain water areas.

THE WIRE DRAG.

Until quite recently the lead-line method was the sole dependence of the chart maker. That it is untrustworthy as applied in many localities is apparent. With the recent greatly increased importance and exacting requirements due to the deeper draft vessels, the opening up of new water areas, the greater demands of our Navy, and in general a greater necessity for absolute accuracy owing to frequent marine disasters, its defects became alarming.

The most important forms of these menaces, not generally found by the use of the older method, are rocky pinnacles, ledges, bowlders, coral reefs, etc. As surveys by the lead-line method failed frequently to reveal even an indication of their presence, it became more and more evident that some new device specially adapted to the requirements of such localities was urgently needed.

For this purpose the wire drag was adopted. From its crude original form there has been rapidly developed, by the Coast and Geodetic Survey, an apparatus which in practice gives absolutely accurate results that are final.

It consists of a horizontal bottom wire, supported at intervals by adjustable upright cables suspended from buoys on the surface. These uprights can be lengthened or shortened for various required depths, and to maintain the bottom wire at a given depth below the surface of the water by making allowance for the rise and fall of the tide. The uprights are maintained in a nearly vertical position by means of weights attached to their lower ends.

Intermediate between the uprights wooden floats are attached directly to the drag wire to prevent sagging between the uprights. The end weights and buoys are larger than the intermediate, and to them the towing gear from the launches is attached.

OPERATION OF THE WIRE DRAG.

In operation the drag is extended by directing the course of the launch outward from the middle of the drag as well as forward along the center of the area to be swept. In some instances the forward motion of the drag is due entirely to the current, and when this is the case the effort of the launches is expended entirely in maintaining the drag in an extended form. An interesting feature of the apparatus is the signaling system between the end launches, made necessary on account of the great length of the drag, which is sometimes four to five miles long.

Upon meeting an obstruction in its course the drag at once indicates the obstruction and points out its location. As soon as the drag wire touches the obstruction there is a marked increase in the tension on the drag, which is noted immediately on the spring balance to which the tow line is attached; and the position of the shoal is shown by the buoys, which line up between the obstruction and the launches. A buoy is then placed at the intersection of the two lines of drag buoys, the drag is cleared and moved ahead on its course, and the detailed examination of the spot is then made by a sounding party in a small tender or sounding boat.

The great length of the drag and the maintenance of an ample overlap along adjacent dragged strips insure the completeness of the operation; and the stability of the drag wire at the required depth, and its certain indication of any contact with the bottom, give ample assurance of the certainty of its results.

The hydrographic survey completes the field work. As a result of the several operations in the field we have some books with the various records of observations and sheets on which are represented the topographic and hydrographic features. This information must be arranged in the most serviceable form for the mariner and placed on metal plates in order that it may be printed for general distribution and sale. This is the duty of the office force.

OFFICE WORK IN MAKING THE CHART.

The computers make the precise computations necessary to accurately show the latitude and the longitude of each of the control points, the variation of the magnetic needle, the direction and strength of the currents, and the plane of reference, which is the mean of the low waters to which the observed depths of water are reduced.

All material received in the office affecting nautical charts, including surveys by the United States Coast and Geodetic Survey, other branches of the Government, State and municipal officials, and by other authorities, is referred to the drafting room where it is indexed for ready reference.

The hydrographic work of the Survey is usually received with the soundings plotted on the field sheets in pencil. These are verified and inked before being used for charting purposes.

The first step is the determination of the scale of the proposed chart. The commercial importance of the locality, the characteristics of the bottom, and the area to be covered are the controlling factors in determining the scale.

A drawing on paper, known by the draftsman as *the rough drawing*, is then made. Lines representing arcs of parallels of latitude and meridians of longitude are drawn and verified. This system of lines is known as the *projection* and serves as the control of the drawing. On the published chart it enables the mariner to plot the position of the ship when its latitude and longitude are known; or to scale the latitude and longitude of his ship's position from the chart when such position has been determined graphically on the chart by dead reckoning or bearings on shore objects.

The next step is to reduce and draw in the shore line and such topographic features as are to appear on the chart, special consideration being given to those features that will be useful to the mariner in determining the position of his ship. All objects of prominence which can be seen from the water areas, such as lighthouses, beacons, range marks, church spires, towers, etc., are carefully plotted on the drawing by means of their geographic positions as determined by the triangulation. All other topographic features are compiled from the plane-table sheets.

In order to make safe entry into harbors, roadsteads, etc., the mariner consults the chart for soundings noted thereon. At the same time, however, he must allow for the state of the tide at the time. This information is obtained from the tide table, which, published annu-

ally one or two years in advance, gives the times and the heights of high and low waters of practically all the coastal waters in the world visited by ocean-going vessels.

Only with the aid of a specially designed machine is it practicable to master the amount of the computations required to predict these heights and times with the necessary accuracy for so many stations. This machine, when set for a particular station and some future year, takes into account the tide-producing forces of the sun and moon, as known astronomically, and the modification of their effects by the conditions peculiar to the particular station, which latter are determined once for all by the analysis of a series of tidal observations at the place made in the past. These data, kept on file, are set in the machine. This requires about two hours. In about seven working hours the operator tabulates, on a form ready to go to the printer, the day, hour, and minute, and the feet and tenths of each high and low water in one year for that station.

DEPTH CURVES AND SOUNDINGS.

The *soundings* and then the *depth curves* which connect all points having the same depth, 5 fathoms for instance, are added to the drawing. As the field sheets are usually on a much larger scale than the chart and have as many of the soundings as can be plotted on the sounding lines, only a small percentage of such soundings can be shown on the chart. The accuracy and clearness of the chart depends on an intelligent selection of the soundings. Critical depths which mark changes in the slope of the bottom must not be obscured by crowding in less important ones, and the selection must be made to show clearly all safe areas as well as all dangerous features developed by the surveys. The nature of the bottom material is also indicated at frequent intervals. The curves connecting points of equal depth are of great value in showing the general configuration of the bottom, in emphasizing shoal spots, and in indicating the areas over which ships of known draft can be safely taken. To guard against mistakes the drawing is verified by other draftsmen, and after verification it is examined and approved by the chief draftsman.

ENGRAVING AND PRINTING.

If the chart is to be engraved on copper, the drawing is then turned over to the engraver. If it is to be published by lithography, which is usually the case, as the chart will then reach the public much sooner, a finished drawing is made on tracing cloth. All the artistic skill of the draftsman enters into this drawing, limited by the rigid requirement that every line and dot made in the drawing must be absolutely opaque.

Owing to frequent changes, the buoys, beacons, range marks, and range lines, and the characteristics of the lights are added to the copperplate or finished drawing just before the chart is printed.

The chart reaches the public through three different processes of printing. First, by a direct print from copperplate; this process gives the clearest possible chart and is used especially for charts of small scale covering extensive areas or those having detailed information. Second, by transfer from the copperplate to an aluminium plate and then printing by the lithographic process. Third, by transferring directly from a drawing to an aluminium plate and printing by the photolithographic process.

SUMMARY.

Starting with a point; then a line from this point; a triangle from this line; new triangles formed on the first; signals over triangulation points; topography filled in by plane table; hydrography surveyed; computations made; compilation sheet drawn; smooth drawing made; plate engraved; plate electrotyped; the chart, printed or lithographed, then goes to the mariner.

The charts are sold for amounts which cover only cost of the paper and the printing.

The outline is simple, but long years of training in each branch is necessary to prepare the officers of the Survey to make this important safeguard to human life and property which also makes accessible new lands and their products.

THE TIDE CALCULATING MACHINE.

One of the wonders of the office of the United States Coast and Geodetic Survey is the tide calculating machine that can prophesy the height of the tide at any desired place in the world at any future date, or the time of high or low tide. Tidal observations are first taken at the desired place and the components thus obtained are set up in the tide machine, which was designed and perfected in the office of the United States Coast Survey. These components represent the forces acting on the tides, such as the attraction of the moon and sun, the density of the earth, together with a number of other factors, thirty-seven in all, and the turning of a crank on the tide machine integrates the factors, and automatically performs, in a few hours, calculations that would take an expert mathematician several months. The results of these operations are shown on a series of dials, and at the same time a curve is drawn showing the condition of the tide throughout any desired period of time. It is by the use of this wonderful machine that the elaborate tide tables published by the Government are constructed, and could hardly be produced by any other means.

These tide tables give the time to the minute, and the height to the nearest tenth of a foot of every high and low tide during the year for some seventy of the principal ports of the world, and, by means of an auxiliary table, the same information for about three thousand other places.

Microscopic Stops*

WITH reference to stops at the back of the objective, in pre-achromatic times objectives were always stopped down; otherwise the image would have been blotted out by the fog of spherical and chromatic aberrations. I have experimented with old non-achromatic lenses, and have taken the stops out, just to see what the images were like without them. After the achromatic lens was introduced stops did not altogether disappear, because some of those early achromats were very bad and required much stopping down. In the forties and fifties, owing to Lister's improvements in the construction of object-glasses, stops became rarer; but about fifty years ago stops were revived for the purpose of increasing penetration, and objectives were sold with stops for that purpose. It was a point strongly advocated by Dr. Carpenter; but about that time there was another prolific writer upon things microscopical, whose idiosyncrasy was to give grandiose, and often classic, names to the simplest things.

It was Dr. Royston Pigott who substituted an iris diaphragm for the homely stop, and rechristened it "Dr. Royston Pigott's aberrameter"! (The iris diaphragm was a new thing then, and had only lately been applied to the microscope by Richard Beck; the iris did not get as far as a camera lens for many years.)

Soon after this "the aberrameter" became known as "the Davis shutter." Then this idea was taken up by Prof. Abbe, and little intermediate screw pieces were supplied for attachment between the lenses and their mounts; they were cheap (one shilling), well made, and easy to apply.

I have a Ross ½ (Wenham) of 80 degrees, N.A. 0.64, which has two stops cutting it down to 60 degrees and 40 degrees. It is forty years old, and this type of lens was the best at that time, and remained so until the apo. 12 millimeters of 0.65 N.A. was introduced in 1886. This Wenham lens is rather overdone at its full aperture, but it performed harum scarum resolutions with slots, etc., very well; e. g., it resolved the Cherryfield rhomboides, which feat took the then microscopical world by storm. But with the 60-degree stop (0.52 N.A. measured) it is as good as any modern lens; of course, it has no Jena glass in it, but its lenses are as bright and as clear as the day they were made.

Personally, I do not think there is much in this cutting down of the aperture of a lens to increase its penetration. If a duffer prefers to use a 1-6, where an average microscopist would use a 1-inch, then, of course, a stop to reduce the aperture of the 1-6 from 0.8 to 0.2 N.A. would be of service. But the cutting down of a ½ of 0.5 or 0.4 to 0.3 N.A., or of an inch of 0.2 to 0.1 N.A., can serve no useful purpose.

The real value of these stops is seen with dark grounds, and for this reason: When you have a dark ground the whole aperture of your objective is utilized —and this is what very few object-glasses will stand. With transmitted light we know that we are generally restricted to a ¾ cone, and there are some lenses that won't even stand as much as that, so have to be used with a ½ cone.

With the dark ground, however, it is a case of full cone, and the only way to meet this condition is to place a stop at the back of the objective to sharpen up the image. Of course, the stop has another function besides, for it makes a velvety dark ground a thing of easy attainment. While this letter was written experiments were made with forty or fifty object-glasses from 4 inches to ¼ inch, with a result that some interesting points have turned up.

First, it appears that stops are most required in those lenses which have a large optical index.

$$\text{O. I.} \frac{1000 \text{ N. A.}}{\text{initial power}}$$

We should naturally expect that this would be so, for lenses with a large O.I. have large back lenses, and, therefore, are more likely to possess outstanding spherical aberration. Putting it another way, it may be said that lenses with a small O.I. have already the stop in them, and so do not require another. The normal O.I. is 25; this is reached and even exceeded in the lower powers, but optical science has not yet attained to this in higher powers, so we see a great falling off, e. g., a 1-6 with O.I. 15. If, for example, two well corrected 2-inch objectives were exhibited, one having N.A. 0.125 and the other N.A. 0.075, everyone would, without hesitation, pick out the lens of 0.125 N.A. as the better. But the same individual might probably refuse to understand that a 1-6 of 0.90 N.A. ranks *pari passu* with a 2-inch of 0.075 N.A.! Both these lenses have an O.I. of 15. If the 1-6 is to rank equally with the 2 inches of 0.125 N.A. it must have an aperture of 1.5 N.A., so that both may have an O.I. of 25.

Another important point, not generally known, was brought to light. The objects examined on the dark grounds were carefully selected, so that there should be no fine detail of a minimum resolution kind. The first for low powers, 4 to 2 inches, was a common foram: semitransparent ammonite sort with spots (*?Nonionina crassula*); the spots could be easily seen with the 4 inches and B eyepiece.

With this object the crucial condition seemed to reside, not in the stop at the back of the objective, but in the size of the opaque stop at the back of the substage condenser; for if this stop were not pretty large the image was sure to be a poor one. It mattered little whether the condenser was achromatic or chromatic, but the thing that did matter was the largeness of the stopped out cone. To put this in figures: there were seven graduated opaque stops. No. 1 just made the field dark, but Nos. 5 and 6 gave the best image.

For medium powers from 2 to 2-3 inches a very coarse Triceratium was used, the quality of the image being judged from the appearance of the primary structure, and the valve taken as a whole. It may be of interest to record that the secondary structure on this diatom was seen with a 1 inch. The 24-millimeter apo. 1888 O.I. 29, as might have been expected, gave the best image, but the next best, which was very close to it, was with *mirabile dictu!* a High Powell 1 inch of 1840, O.I. 23.

With a wide-angled 1½ inch a kind of resolution can be seen, but it is doubtful if this is a true resolution, for the structure in question consists of dots running in lines which radiate from the center of the valve. Now, obviously, these lines can be resolved by an objective of smaller aperture than would be required to resolve the dots.

Again, the false Abbe resolution, arising from a hexagonal structure, consists of six dots around a single one. If this ghost image (which is the only kind of image that Abbe and his followers deal in) is super-imposed on a line resolution of these secondaries you have precisely the sort of resolution seen with a 1½-inch objective. The resolutions with the inches are quite different, and are undoubtedly genuine images. Five-and-thirty years ago the existence of these secondary structures was strongly controverted at the R.M.S. much in the same way as other structures have been in recent times, and yet they can be seen with an inch!

This, however, is a digression; but to return to our subject, the same phenomena were observed with these powers, ranging from 2 to 2-3 inches, as were noted with the lower powers. Stops at the back of the objective only did good when excessive O.I. had to be reduced, but the size of the opaque stop at the back of the substage condenser had considerable effect upon the image.

The test used with the ½, 4-10, and 1-3 objectives was a coarse *Navicula lyra*. With these lenses a stop reducing the apertures to 0.5 N.A. was of service, and for the reason given *supra*, that a good dark field could be easily obtained with a stopped down objective an 0.65 N.A. stop at the back of a ¼ was useful.

An iris in an ordinary nosepiece works very well with lower powers, but not with the higher powers. Stops cut out of a postcard and pushed down on to the back lens of the objectives are quite satisfactory; but the best thing that has been done in this direction is the interior iris, designed by Mr. Traviss, which fits close to the back lens. I have a 4/10 fitted with one of these, and find that it works perfectly; but the postcard stops can be made in a few minutes, cost nothing, and work perfectly well.

To sum up, stops with low powers are hardly wanted. With medium powers stops to 0.5 N.A. will be found advantageous, and a ¼ inch with a 0.65 N.A. stop and a B or C eyepiece is a useful combination for Pond Life on a dark ground. Finally, the term "penetration" really means the improvement in an image owing to the presence of a stop at the back lens of an indifferent objective.

*Edward M. Nelson in *The English Mechanic*.

Optical Appliances in Warfare*

A Survey of the Principles of Construction of Some of the Important Instruments

By Charles R. Darling, A.R.C.Sc.I., F.I.C.

In dealing with the optical appliances used in the field, which comprise a large number of separate items, it is not possible to give a detailed account of each, as a whole paper might be devoted to a single class of instruments, such as range-finders. In the present paper, therefore, it is intended to take a general survey of the whole subject, so as to convey an idea of the nature of the optical instruments used and the purposes they fulfill.

The following are the chief optical appliances used in warfare:

1. Field glasses and telescopes.
2. Searchlights.
3. Periscopes.
4. Range-finders.
5. Signaling lamps and heliographs.

In addition to the above, cameras, prismatic compasses, surveying instruments, etc., are used; but it is only proposed in the present paper to deal with appliances specially devoted to warfare, and embraced in the above five headings, which will be treated in turn.

FIELD GLASSES AND TELESCOPES.

As an aid to vision, field glasses or telescopes are essential in military operations, and a number of different patterns, varying according to circumstances, are in use. Binoculars on the principle of the Galilean telescope possess several drawbacks as compared with modern prismatic glasses, notably that the field of view is small and the magnification low, and also that cross wires cannot be introduced, owing to the fact that no real image of the object is produced. On the other hand, they give good illumination, and in a dull or dark atmosphere may be used to advantage. Patterns with magnifying powers of three, four and five, respectively, are in use, having fields of view ranging from about 3 degrees to 4 degrees 30 minutes.

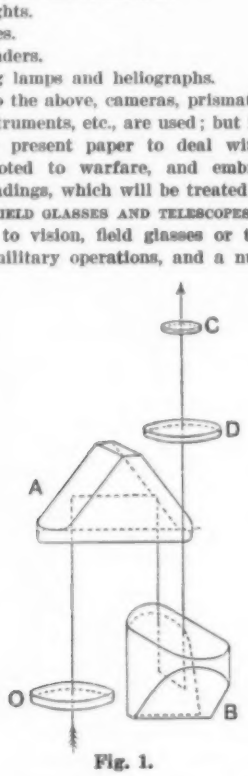


Fig. 1.

The prismatic binoculars introduced by the firm of Zeiss have the advantages: (1) That a long focus object glass may be used in a short body; (2) an increased field of view is obtained, with greater stereoscopic power, by placing the object glasses further apart than the eyepieces; and (3) a real image of the object is formed, enabling cross wires or graticules to be used. The path of the central ray through one side is shown in Fig. 1. The object glass *O*, in the absence of prisms, would form an inverted image of the object; but in passing through the prism *A* the image is reversed from left to right, and in *B*, which is placed at right angles to *A*, the image is reversed vertically, an erect image thus being formed in the focal plane of the eyepiece, which is composed of two lenses, *C* and *D*, which magnify the image without inversion. In effect, this arrangement is equivalent to an ordinary telescope, of length equal to the path of the central ray; and as the magnifying power is equal to

$$\frac{\text{Focal length of object glass}}{\text{Focal length of eyepiece}}$$

it is evident that a great advantage is gained by lengthening the path of the ray and increasing the focal length of the eyepiece. Patterns are issued with magnifying powers of six and eight, and with fields of view ranging from 4 degrees 30 minutes to about 8 degrees 30 minutes, figures which show a marked advantage over the Galilean type. In some of these graticules are fitted in the focal plane of the object glass. These consist of a number of lines ruled on a glass plate, spaced out so as to represent minutes of deflection to right and left, as shown in Fig. 2, which assist in accurately determining the position of an object in the field of view. If rotated through a right angle, the graticules may be used similarly for elevated objects, the dimensions of which may thus be estimated.

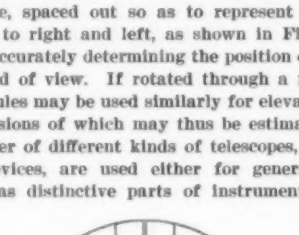


Fig. 2.

A number of different kinds of telescopes, fitted with special devices, are used either for general observations, or as distinctive parts of instruments, such as directors or gun-sights, the magnifying power ranging from three to thirty-five. In some patterns the magnification may be varied over a large range—from five to twenty diameters—by a single movement, without disturbing the focus of the sighted object. This is accomplished, in the Ross pattern, by moving the erecting lens further away from the eyepiece, that is, nearer to the image formed by the object glass. The size of the upright image, viewed by the eyepiece, is thereby increased, and the final image is correspondingly magnified. If the erecting lens alone were altered in position, the object would no longer be in focus; but by means of a mechanical device the eyepiece is made to move simultaneously by the amount necessary to retain the focus. The advantage of a variable power telescope is that the low power may be used as finder, while the high power can be brought in for better definition without changing the focus. The initial adjustment is carried out by means of a movement independent of that which produces the change of power.

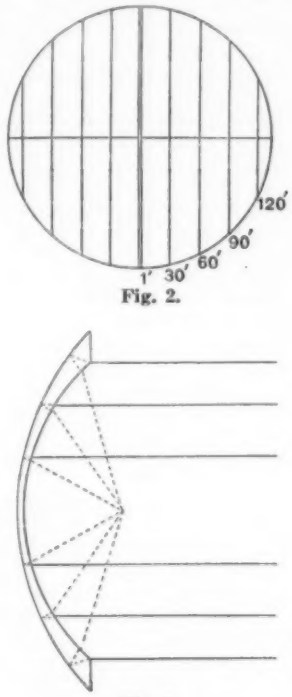


Fig. 3.

When telescopes are used as gun-sights, a pointer, or sighting wire, is placed in the focal plane of the object glass, where the image of the target will be formed, and when the image is seen to coincide with the assigned mark the aim is correct. This method of sighting is preferable to the alignment of the target with a fore-sight and back-sight, as in this case the eye cannot be focused for all three points at once, and a greater or less degree of uncertainty results; whereas with a telescopic sight both target and auxiliary mark are in focus at the same time. Telescopic sights have also been applied to rifles, a similar advantage being gained. When a telescopic sight is used at night it is necessary to illuminate the lines or pointer, and this is usually accomplished by means of a small electric lamp inserted in a suitable position in the telescope.

For observing the effect of artillery fire, the stereotelescope, also due to the firm of Zeiss, is much used, as its stereoscopic power enables a much better judgment of distances to be formed than in the case of an ordinary telescope. This instrument is a binocular with hinged tubes, which may be moved to any desired angle between the vertical and horizontal, the stereoscopic power increasing as the distance between the object glasses becomes greater. Rays from the object enter each tube by a window, in front of which is a prism which reflects the light on to the object glass, and by means of two prisms at right angles the rays are brought into the eyepiece. This telescope may be used with the tubes at any angle, or an object may be sighted over a wall or parapet without exposing the observer. One pattern in common use has a magnifying power of ten diameters, with a field of view of 4 degrees, and has one eyepiece fitted with a graticulated diaphragm, which may be used horizontally or vertically, for accurate observation of positions.

SEARCHLIGHTS.

The searchlight does not play a prominent part in land warfare under present conditions, as it would be too conspicuous an object, and when illumination is required star shells are used. As a means of sighting air craft, for coast defence, and for naval purposes, however, the searchlight is indispensable. The source of light is an electric arc, fed by clockwork, which is placed at the focus of a concave mirror. This mirror forms the end of a tube out of which the reflected rays are projected, and which is mounted on a base so as to be capable of horizontal or vertical movement. As the focus of a mirror is a point, it is evident that only one point of the crater of the arc can occupy this position, and rays emanating from this point, after reflection, will proceed in lines parallel to the axis of the mirror. From all other portions of the crater, however, the rays will be reflected from the mirror at an angle to the axis, the value of which, under working conditions, is 2 degrees or 3 degrees. Hence the beam as a whole is divergent, and lights up a much larger area than that of the mirror itself; whereas, if all the rays were parallel the illuminated area would only be equal to that of the mirror. At a distance of 2,000 yards the illuminated area, owing to this divergence, usually has a diameter of 100 yards, and enables objects comprised in this area to be clearly seen. The shape of the mirror or reflector is a matter of the greatest importance if a satisfactory beam is to be obtained. A spherical surface, owing to the aberration produced by the edges, is not suitable. In the reflector invented by Col. Mangin, of the French Engineers (Fig. 3), this difficulty was overcome by the use of a glass mirror, silvered at the back, the front face possessing a greater curvature than the outer face, so that the reflector was thicker at the edges than at the center. The rays, being more refracted at the edges, were thus made to escape in a direction parallel to the axis when emanating from the focus, thus correcting for aberration. These reflectors gave an excellent beam, but being made of glass were liable to breakage, either in transport or due to the heat of the arc, and have

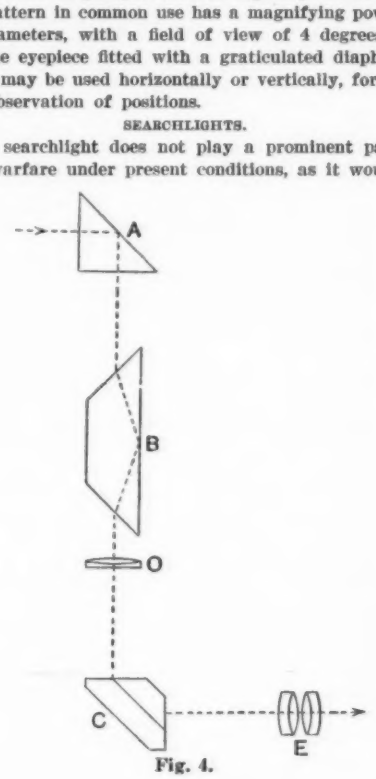


Fig. 4.

*Journal of the Royal Society of Arts.

now been almost entirely superseded. For ordinary working paraboloid mirrors, made of metal, are now used, the reflecting surface being of silver or gold, or occasionally palladium or nickel. When it is desired to light up a large area at short range, the mirror used is parabolic in vertical section and elliptical in horizontal section; the focus of the parabola coinciding with one of the foci of the ellipse. As all rays emanating from one focus of an ellipse pass after reflection through the other focus, the beam spreads out horizontally, but retains its normal dimensions vertically owing to the parabolic section. The amount of lateral dispersion produced in this manner may be as much as 45 degrees, and hence a large area may be illuminated. An alternative method of producing a diverging beam is to place a number of positive cylindrical lenses in the path of the beam side by side, each of which brings the rays from a portion of the mirror to a focus on a line beyond the lens, from which the rays afterwards diverge. By using two rows of lenses, that nearest the mirror being fixed while the outer row is movable, any desired degree of dispersion may be secured. This form is generally used for naval purposes, and has the advantage of enabling one form of beam to be adapted to all conditions. The diameters of the reflectors used range from 120 centimeters (nearly 4 feet) to 35 centimeters (14 inches); and the focal lengths from 65 centimeters (25.5 inches) to 15 centimeters (6 inches).

The carbons used for the arc vary in size, according to the current used, and are placed horizontally. The positive carbon, in which the crater is formed, faces the mirror, and is made of larger diameter than the negative, and is provided with a graphite core in order to keep the crater central. The smaller size of the negative carbon results in less obstruction of the light from the crater. The diameter of the crater ranges from 9 millimeters in a 20-ampere lamp to 23 millimeters in a lamp taking 150 amperes, the diameters of the positive and negative carbons being 18 millimeters and 12 millimeters, respectively, in the former case, and 38 millimeters and 26.5 millimeters in the latter.

There are many optical principles involved in the structure of a searchlight beam which cannot be entered into in detail in a paper of this description, and accordingly only conclusions will be given. Each point on the mirror reflects the image of the crater, and sends out a cone of light; the cones emanating from the central part having nearly circular bases, while those reflected from the edges have elliptical bases, as the projection of the crater on these portions is an ellipse. The resultant beam is a blending of these cones, and consists of an evenly illuminated center, round which the brightness diminishes to zero at the edges. The cones from the central portion of the mirror have dark centers, owing to the negative carbon shutting off some of the light of the crater, and the reflected light from the edges also possesses a dark portion, though not central, due to the same cause. All these points may be noted on looking at the projection of a searchlight beam on the clouds.

The following laws hold good for the beam:

1. The diameter of the illuminated area is proportional to the diameter of the crater.
2. The diameter of the illuminated area is independent of the area of the mirror.
3. The diameter of the illuminated area is inversely proportional to the focal length of the mirror.
4. The diameter of the illuminated area is directly proportional to the distance from the projector.
5. The intensity of illumination is independent of the size of the crater, and of the focal length of the mirror.
6. The intensity of illumination is directly proportional to the area of the mirror, and inversely proportional to the square of the distance from the projector.

From these laws it may be gathered that the greater the area to be illuminated, the larger must be the diameters of the mirror and crater.

In order to secure a steady light, the voltage at the lamp terminals must be kept constant. A 90-ampere arc, for example, requires 56 volts, and the supply voltage must be reduced to and kept at this figure by the use of a series resistance. The carbons should be homogeneous, so as to secure a crater of unvarying shape, and should be correctly aligned. The management of a searchlight demands considerable skill, and the large number used for home defence has entailed a demand for operators with electrical knowledge, which, fortunately, our technical colleges have been able to meet.

PERISCOPES.

Strictly speaking, a periscope is an instrument in which the whole surroundings of an observer may be viewed through a fixed eyepiece. For naval work, and particularly for submarines, these instruments are invaluable, as observations may be made with nothing but the top of the instrument projecting above the water. A periscopic gun-sight also enables guns to be

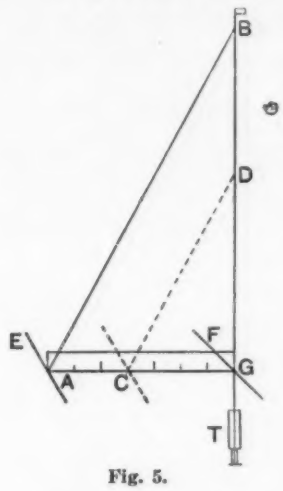


Fig. 5.

laid behind cover, and enables auxiliary marks to be used without the gunner having to change his position. The principle of the periscope is shown in Fig. 4, in

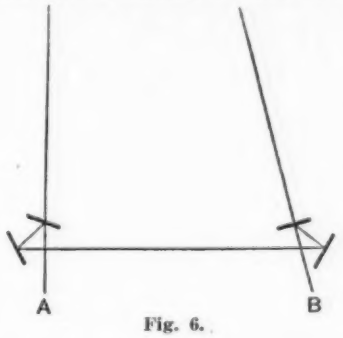


Fig. 6.

which the path of the central ray is indicated. The upper prism *A* is mounted on a cowl, so as to be capable of revolution in a circle. Rays from the object are

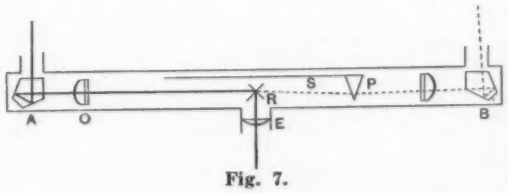


Fig. 7.

reflected from its sloping face into a second prism *B*, the longer vertical face of which acts as reflector. The rays then pass through the object glass *O*, and thence

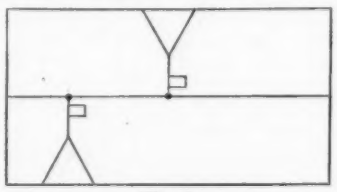


Fig. 8.

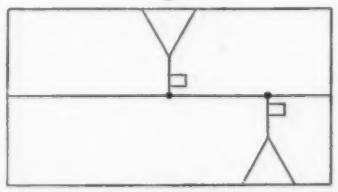


Fig. 9.

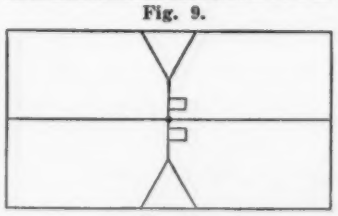


Fig. 10.

through a third prism *C*, known as a "roof" prism, which turns the rays at right angles into the eyepiece *E*. The prism *A* inverts the rays vertically, but by passing through *B*, which also inverts vertically, this effect in *A* is counteracted and an upright image enters the object glass *O*. This lens inverts the rays both horizontally and vertically, but the prism *C*, in which two reflections occur, restores the rays to the original directions, and hence a correct image is viewed by the eyepiece, which magnifies without causing inversion in either direction. When the prism *A* is revolved, *B* is caused by an attached mechanism to move at one half the rate, and as the angular movement of a ray is twice that of the mirror which produces it, the rays will always fall on the object glass in the same direction, whatever may be the position of *A*. The upper prism may be placed at the end of a tube at any desired height above the observer.

Many modifications of the above arrangement exist in periscopes of different makes; the general principle, however, is the same.

RANGE-FINDERS.

The first range-finder of which I have been able to discover a record was designed by James Peacock, architect, of Finsbury Square, and published in a book entitled "A Repertory of Arts, Manufactures and Inventions" in 1794. This range-finder is interesting from the fact that it is a "one-man" instrument, with a short base, relying for its accuracy on optical perfection—resembling in this respect the most recent instruments. The principle is indicated in Fig. 5, where *A G* is a scale to one end of which is fixed a flat mirror *F*, inclined at 45 degrees to the edge of the scale. A telescope *T* is fixed at right angles to the lower edge, so that its cross wire is exactly opposite the end. At the other extremity of the scale is placed a second flat mirror *E*, fixed at a definite angle, but capable of horizontal motion along the scale. In marking the scale to read ranges, it was proposed to light a candle at one end of General Roy's five-mile base and to view the light through the telescope from the other end of the base, the upper portion of *F* being left unsilvered for this purpose. The mirror *E* was then to be tilted so that the reflected image, after falling on the silvered part of *F* and passing into the telescope, was exactly in line with the direct image, in which position it was to be securely fastened so as to retain its inclination. The extremity of the scale *A* was then to be marked five miles, and *G* zero, the part in between being divided into equal divisions of any desired size. The range could then be read off directly by observing the position of *E* when the images coincided; thus the range *G D* would be represented by *C G* on the scale, since $\frac{GD}{GB} = \frac{CG}{AB}$. It was suggested that the instrument would be useful to surveyors—in those days the accurate, long range gun had not been invented—but there is no mention of its actual manufacture. The idea, however, is sound; and with modern appliances might probably be worked up into a satisfactory range-finder.

In the demand for range-finders, caused by modern guns, the instruments at first used—and not yet entirely extinct—required two observers, and a long base was adopted with a view to accuracy. The service "mekometer" (Fig. 6) is an example of this type. An observer stationed at *A* uses an instrument containing two mirrors inclined at 45 degrees to each other, the upper mirror being unsilvered in its upper portion. On looking at this mirror he sees the target through the upper part directly, and, by reflection, a white mark on the instrument of the second observer. When target and mark appear in line, the base is at right angles to the target. The observer at *B* uses a similar instrument, except that the lower mirror may be moved by a milled head, which must be turned until the target coincides with the white mark on the instrument at *A*. The angle could then be determined and the triangle solved; but to save calculation the range is marked directly on a drum which rotates with the milled head. The base used is 25 or 50 yards long, according to pattern, and consists of a stout cord with hooks at the end to fasten to the instruments. Simple as the mekometer seems, it is not easy to obtain very accurate results by its use. The cord cannot be pulled perfectly straight, and variations in the amount of droop alter the result. Small errors in aligning the target and the white mark also cause notable errors in the reading, and it is not uncommon for beginners to return results varying by 20 per cent, even when using the same instruments and target. Two skilled observers, however, using a 50-yards base cord, should take a range of 2,500 yards with an error not exceeding 2 per cent.

The "Field Telemeter" consists of a single instrument, but requires two men to use it in taking a range. It differs from the mekometer in the respect that a base of any suitable length may be used. The actual length of the base chosen for the occasion is measured

by the instrument, the standard of reference being a steel tape six or nine yards long, according to the pattern. This tape is run out at right angles to the base at one end, and serves as a sub-base for the measurement of the working base. A sliding collar, moving over a graduated bar, is then set at the figure corresponding to the measured base, the position of this collar determining the amount of angular movement imparted to the movable mirror by the adjusting screw. The range is read off from a drum which rotates with the adjusting screw; and whatever length of base be chosen, the same figure will be obtained, provided the sliding collar be correctly set on the bar. A detailed description of this instrument would not be possible within the limits of the present paper. It may be stated, however, that the field telemeter is superior to the mekometer, particularly for long ranges; and practised observers can obtain readings up to 5,000 yards with an error not greater than 2 per cent. The Watkin Field Range-Finder is a similar instrument.

All range-finders requiring two observers and the setting out of a base line suffer from the defects, (1) that a considerable time—possibly five minutes—is required to obtain the range; and (2) that the ranges of moving objects cannot be taken continuously. For these reasons, both for naval and military use, "one-man" range-finders are found preferable. The type introduced by Profs. Barr and Stroud is now generally employed, and gives very satisfactory results, although its construction is more delicate than that of "two-men" instruments. Fig. 7 indicates the arrangement of parts in the Barr and Stroud range-finder, which consists of two telescopes with a single eyepiece. Rays from the distant object enter the five-sided prism *A* through a window, and as the sides of this prism are inclined at 45 degrees the emerging ray escapes at right angles to its original path and passes through the objective *O* to the central reflecting prisms *R*, from whence it enters the eyepiece *E*. The rays entering the right-hand prism *B* follow a similar course through the objective; but, owing to the length of the tube, such rays will enter *B* at a different angle to which rays from the same point enter *A*, and will pass through the tube inclined to the horizontal. This inclination will evidently vary with the distance of the sighted object; and, if the rays were permitted to pass unchanged to the central reflectors, and so to the eyepiece, the image of the object would not coincide with that formed by the system on the left. By interposing an adjusting prism *P* in the path of the inclined rays, however, they may be turned into a horizontal position, when coincidence of the images will occur. The correct position of *P* depends upon the inclination of the rays which enter it—that is, upon the distance of the target; and hence this position may be used to define the range by attaching a range scale *S* to *P*, and noting the reading opposite a fixed point.

The method of obtaining coincidence is indicated in Figs. 8, 9 and 10. The arrangement of the central prisms is such that the image due to the left-hand telescope is inverted, while that formed by the right-hand side is erect, both being seen in the eyepiece divided by a central line. In Fig. 8 the adjusting prism is too near the center, and gives an image displaced to the left; in Fig. 9 it is too far away from the center, the image now being too far to the right; while Fig. 10 shows the correct position, the images being coincident. In the actual instrument, a second lens is provided, near the eyepiece, through which the range may be viewed simultaneously with the image. The following are some particulars of the instrument: Total length, 44¼ inches; working base, 1 meter; weight, 13½ pounds; magnification of telescope, 13; field of view, horizontal, 3 degrees 10 minutes; field of view, vertical, 2 degrees 40 minutes; range scale graduated from 500 to 20,000 yards; accuracy, 2½ per cent at 5,000 yards. Readings at the highest ranges are only approximations. General experience with the Barr and Stroud range-finder is entirely in its favor, and shows it to be superior to the types which require two observers.

The Zeiss range-finder differs from the Barr and Stroud in the construction of the adjusting prism, which, in the Zeiss pattern, consists of two wedges of glass rotated in opposite directions by a gearing, the deviation of the ray being thereby changed as desired. The same movement actuates the range scale in front of a fixed pointer, opposite which the range is read off after adjustment. This gives a small total length of scale, and in this respect is inferior to the Barr and Stroud.

In the Marindin range-finder the five-sided prisms are replaced by right-angled prisms, which carry the object glasses on their upper surfaces, facing the target. Each reflects the image from its hypotenuse to the central prisms, from whence they pass into the eyepiece. Adjustment to coincidence is obtained by turning a drum on which the scale is marked, and which at its forward end engages a lever fastened to the right-hand prism, which is thereby tilted and alters the position of the image in the eyepiece. The range is read directly from the drum. This instrument, used by infantry, reads up to 8,000 yards, the error at 2,000 yards not exceeding 5 per cent.

The Zeiss stereo-telemeter depends on stereoscopic vision, and has been used to some extent in our own army as well as the German. A pair of transparent plates are placed in a binocular, one in each eyepiece, forming a stereoscopic couple. On these plates are marked arrows pointing downwards in three zig-zag lines. Each corresponding pair gives a single image in relief, and as no two pairs are the same distance apart, the appearance presented is that of a number of arrows overhanging the landscape at progressive distances from the eye. In taking a range, the observer must decide which of the arrows overhangs the target; the distance is then taken as that marked against this arrow. The arrows are marked from 90 to 3,000 meters; but the accuracy depends upon the eyesight of the observer, which should be good and equal in both eyes—a condition which reduces the number of reliable operators to about 20 per cent of an average body of men. If this condition be fulfilled, the error will not exceed 1 per cent at 1,000 yards, or 4 per cent at 5,000 yards.

SIGNALING DEVICES.

In trench warfare signaling by flags, heliograph or lamps is not greatly resorted to, the field telephone being better adapted for communications under these conditions. In open warfare, however, the heliograph is useful for flashing signals by the aid of sunlight. It consists of a circular flat mirror, 5 inches in diameter, capable of being tilted through a small angle by means of a key, and possessing a sighting-vane for laying on to the receiving station. The Morse code is used, short flashes representing dots, and a sustained flash dashes. For night work signaling lamps are used, a parallel beam of light being sent out, which can be cut off by a movable shutter. Some lamps burn oil, others acetylene, and a strong lens is used to produce the parallel beam.

New Method of Treating Electric Shock

THE effectiveness of the policeman's method of resuscitating a soporific tramp by pounding the soles of his feet is well known, but it has only recently been discovered that a similar treatment is of great assistance in treating men suffering from a heavy electric shock. In a recent issue of the *N. E. L. A. Bulletin*, W. P. Strickland, general inspector of the New York and Queens Electric Light and Power Company, of New York City, tells some interesting cases of this treatment.

"Recently one of our foremen after climbing a pole, preparatory to stringing primary wires, received a shock that caused him to fall to the ground. It is inferred that in adjusting his belt and shifting his position his spur cut out, and that to save himself he instinctively reached out and touched the wires carrying 2,300 volts. When the other linemen and ground hands reached him, to all appearances the man was dead. One of the linemen, following instructions, immediately took hold of the ankles of the limp body, lifting it until the whole weight rested on the neck and then letting it fall. He then took a pair of connectors and hammered the soles of the injured man's feet without removing his shoes. Another lineman opened the man's mouth, pulled forward the swallowed tongue (which occurs in electric shock) and was about to begin the Schaefer prone method of resuscitation when the man returned to life. He was removed to the hospital and is alive and well to-day, though suffering severely from his burns.

"For the past year the writer has been teaching his men to strike the feet without removing the shoes in all cases of electric shock. Some years ago an accident occurred where a man came in contact with 6,600 volts, fell from the pole and was restored to consciousness by this means, although he was terribly burned and died three days later. Another accident that came to the writer's attention happened in New Jersey when a man came in contact with a wire carrying 2,200 volts. This man was struck violently on the feet, his tongue was pulled out, and he was restored to consciousness before the arrival of the doctor."

Extraction of Coal Oil by Means of Liquid Sulphur Dioxide

ON treating coal with liquid sulphur dioxide it swells up, disintegrates into fine particles, and yields a reddish extract, which on evaporation of the solvent leaves a heavy mobile oil. When this is treated with sodium bicarbonate solution and distilled in a current of steam, it yields a light oil with faint fluorescence and an odor of petroleum. By extracting the residue with petroleum spirit, yellow oils stable in the air and distilling at 200 to 350 deg. Cent. are obtained. In comparison with benzene extracts made at 275 deg. Cent. the extracts obtained by means of liquid sulphur dioxide contain much less solid substances. This is also the case with the extracts from lignite. When treated with benzene, lignite yields the so-called montan wax, which is a mixture of a wax with resins, whereas the extract obtained from lignite by means of liquid sulphur dioxide is a typical resin.—*F. Fischer and W. Gluud, Ber. From a note in Jour. of Soc. of Chem. Ind.*

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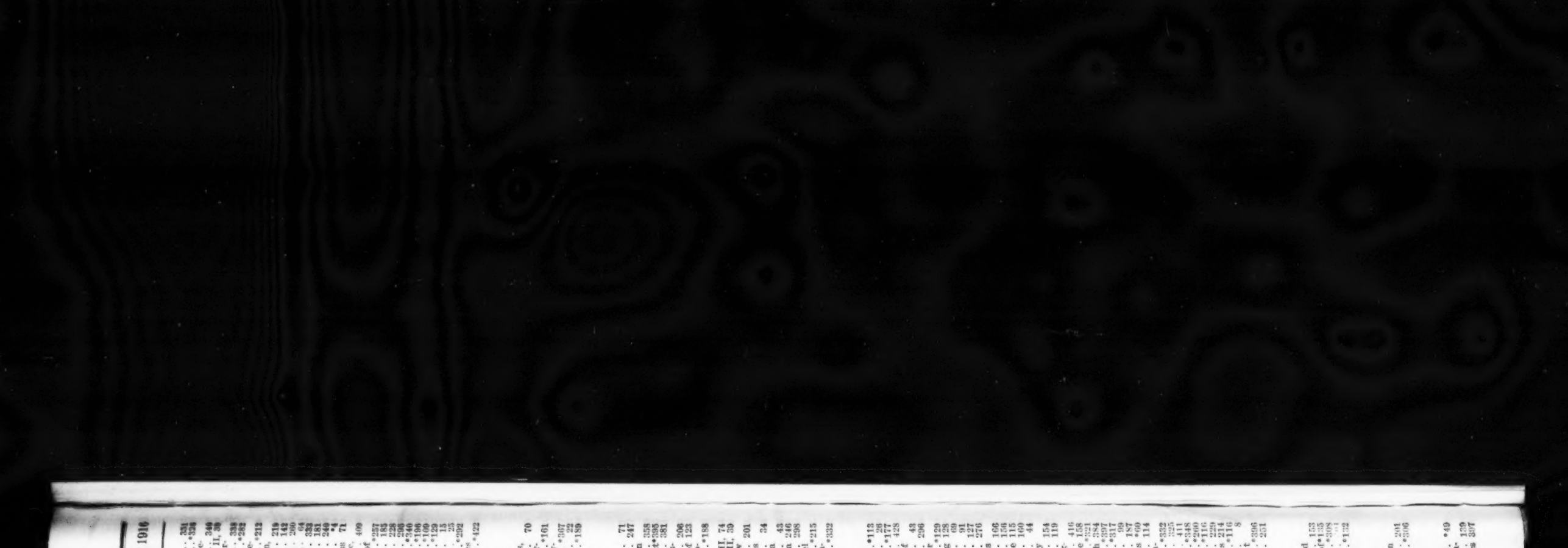
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